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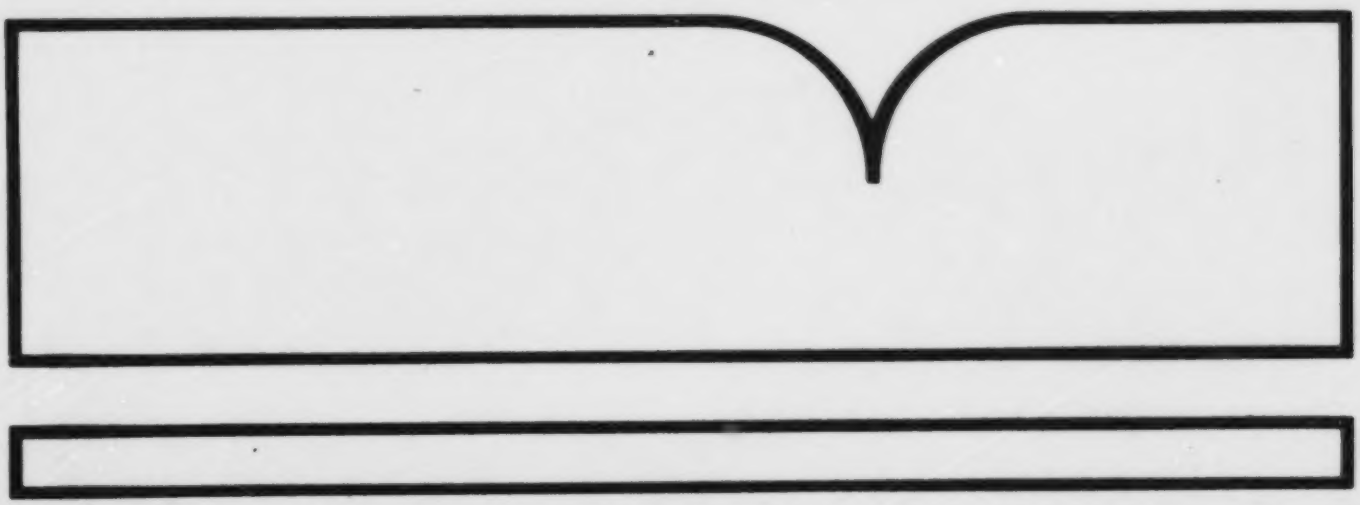

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SELECTED MICROCOMPUTER PROGRAMS FOR WATER QUALITY ASSESSMENTS

(EXPERIMENTAL)

William T. Mason, Jr., Editor

In fulfillment of:
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Water and Land Division
Office of Environmental Processes and
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Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

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16. ABSTRACT

Accompanying this computer program manual is an album of microcomputer disks designed to expedite water quality management information to the states from the regional offices of the U.S. Environmental protection Agency (EPA) and the Fish and Wildlife Service (FWS).

These experimental programs are the product of an Interagency Agreement between the EPA and FWS, with input from the Commonwealth of Pennsylvania and other state and regional agencies.

The programs were selected on the basis of familiarity and common use by aquatic scientists and the potential adaptability of the methods for microcomputer applications. All programs are original, i.e., devised from standard methods by the authors and participants.

The "user friendly" programs are contained on two, 5-¼ inch floppy disks, designed to run on an Apple II Plus microcomputer, disk drive, TV or CRT monitor and printer (optional). The programs will run only on Applesoft Basic DOS 3.3 language. Selection of programs on the menu can be accessed on the Apple IIe model by "shift" and then the "letter." Use of the disks in Apple III requires first formatting using an "Apple II Emulation" program.

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NOTICE

"The Pennsylvania Department of Environmental Resources is currently developing a revised water quality analysis package that will replace the modeling utility contained in this report. This revised modeling package, known as the Water Quality Analysis Model, Version 6.3 (WQM6.3), Release 1.0, incorporates substantial changes and improvements to the current version. These improvements include an array of disk and data management operations. The D.O. Sag Profile and Wasteload Allocation Models have been replaced with a decision model that uses the method of equal marginal percent reduction to determine the effluent limitations for one or more wastewater discharges. The revised version is still being tested and has not yet been approved for general usage. Until it's approval, expected on or about July 1, 1986, the modeling utility package discussed in this report is still the current version."

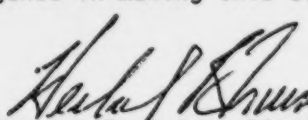
The programs contained in this album are experimental, and therefore, the authors, Editor, and the U. S. Environmental Protection Agency and U. S. Fish and Wildlife Service are not responsible and assume no liability whatsoever for damages to equipment and software resulting from use of the contents of the album nor any possible litigation resulting from use of the programs for water quality planning and management purposes.

PREFACE

This album of microcomputer programs for water quality assessments was initiated as a product of an Interagency Agreement between the U. S. Environmental Protection Agency (EPA) and the U. S. Fish and Wildlife Service (FWS) during detail of Mr. Mason from the National Coastal Ecosystems Team, Slidell, Louisiana, FWS, to EPA, Office of Environmental Processes and Effects Research, Office of Research and Development, Washington, DC.

As part of the State and EPA Regional water quality based approach to pollution control, the quality of water bodies periodically must be evaluated according to attainment of legally established uses. These assessments include a waste load allocation review for priority waters and analysis of water quality status by use of physical, chemical, biological, aesthetic, and economic factors. The microcomputer programs contained in this album are well established, descriptive methods for analysis of waters and their biota. They should provide EPA and FWS Regional Offices with quick reference tools to assist states with their water quality management planning processes.

We appreciate the support of the U.S. Fish and Wildlife Service, the Commonwealth of Pennsylvania and other state and regional scientists for their contributions to this effort. We would especially like to commend Bill Mason for his initiative and diligence in making this concept a reality.



Herbert B. Quinn, Director
Water and Land Division
Office of Environmental Processes
and Effects Research

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ACKNOWLEDGEMENTS

The Editor appreciates the donation of several programs contributed to this album from Mr. Gary A. Lake, Comprehensive Planning Section, Division of Water Quality the Pennsylvania Department of Environmental Resources, Harrisburg, Pennsylvania, Dawn-Dusk-Dawn diurnal oxygen model by Dr. William J. Mitsch, Systems Science Institute, University of Louisville, Kentucky, and the lake morphometry and hydrology program contributed by Mr. Lowell E. Keup, Criteria and Standards Division, EPA, Washington, DC. Mr. Paul Durand, Monitoring and Data Support Division, EPA, Washington, DC, provided valuable recommendations during the course of this project. Mr. Thomas G. Mason and Mr. William P. Mason, Frederick, Maryland, are thanked for valuable programming assistance.

INTRODUCTION

This album of microcomputer programs is dedicated to expediting the analysis and evaluation of water quality assessments, principally as related to the Clean Water Act of 1977 and other legislation pertaining to waters and aquatic life. The programs were selected on the basis of familiarity and common use by aquatic scientists and the potential adaptability of the methods for microcomputer applications. All programs are original, i.e., devised from standard methods by the authors and participants, who are acknowledged preceding each program. The Editor assumes that the user has a general background knowledge of aquatic sciences and knowledge of microcomputers, and the user is interested in application of the information for site planning and management decision-making. Therefore, detailed instructions for microcomputer operations, explanation of mathematical formulas and information on application of results to decision-making are unnecessary. If the user is unfamiliar with the methods, consult aquatic science experts and the "References."

The "user friendly" programs contained in this album are contained on two, 5 1/4 inch floppy disks, the user will need an Apple II Plus[1] micro-microcomputer, disk drive, TV or CRT monitor and printer (optional). The programs will will run only on Applesoft Basic DOS 3.3 language. Selection of programs on the menu can be accessed on the Apple IIe model by "shift" and then the "letter". Use of the disks in Apple III requires first formatting using an "Apple II Emulation" program.

---

[1] Mention of commerical sources does not constitute endorsement by the U. S. Environmental Protection Agency and does not imply any general advantage of equipment and software over other commerical products.

All programs contained in this album (See Contents for listing) have been validated through testing with real data. If the programs malfunction, repeat the directions for booting a disk. If a disk is damaged or programs on the disks are inadvertently erased, information on the disks can not be recovered. Due to limited printing, no replacement program copies are available from EPA, FWS, the authors, or other general reference sources. The programs contained on Disk 2 Pennsylvania Modeling Utility Package" are copyrighted, and should not be reproduced without permission.

OPERATING INSTRUCTIONS

To access the programs contained on the disks follow these steps:

1. Insert the disk, label side up and horizontally, into the disk drive opening and the shut the door securely;
2. Turn the monitor and computer "on" by pressing the switch located on the lower left back of the console (a whirring noise and clicks are normal). This "boots" the program so that the user will see the title page displayed on the screen. After a few seconds, the title page and program menu will display automatically on the monitor.
3. Focus the monitor for best contrast and resolution. Check to see if the printer is "on". Many persons find that a multiple electrical outlet jack, facilitates microcomputer uses because the jack turns on all equipment at the same time, and acts somewhat as a buffer for sudden power surges that can damage and "frack" programs and equipment.
4. Select from among programs listed on the menu by pressing the appropriate letter key shown in the left column. Those programs

on the menu that can be accessed directly by the user are preceded by an "A" on the disk menu. The other programs are support programs to the primary ones. All programs are "user friendly" and will prompt the user for decisions regarding selection of inputs and outputs. However, because programs have been developed by several authors, some queries access automatically by time control while others require a "return" signal to the computer. After a program is completed, the menu can be accessed for another selection. Enter "run hello" to recycle to the disk menu.

5. To print a hard copy of data contained in the computer's memory, enter "PR#1" and "return". This signals the microcomputer to activate the line between the printer and microprocessor. To deactivate the printer enter "PR#0". Some programs have an automatic printer routine. If no hard copy printout is desired, the printer should remain "off". Remember that you can not advance paper in some printers, such as Epson[1], manually with the power "on", otherwise the gears can be stripped. If the power is "on", use the "line feed" control switch on the printer console.
6. To interrupt computer operations, press the "reset" and "control" keys simultaneously. Once a program run is interrupted, the monitor cursor will remain in the left margin and "blink", signaling you to enter another command--like "run hello" This is a safe command as it calls for the program restart.
7. When finished with a disk, place in an individual jacket. Label and store the disks in a cool, low humidity area and away from any magnetism, such as TV monitor, telephone or buzzer that can erase messages on the disk.

8. The Apple microcomputer and most others can be interfaced with a modem to provide networking capabilities. Thus, data stored on large capacity main frame computers can be transferred via phone lines to a local, off line storage device, such as a hard disk drive, and later, accessed time and again at the operator's leisure.

WATER QUALITY ASSESSMENT PROGRAMS
DISK 1

LAKE DIURNAL OXYGEN

William J. Mitsch, Systems Science Institute, University of Louisville, Kentucky.

This program facilitates calculation of primary productivity and respiration of shallow lakes and the epilimnion of stratified lakes. Gross primary productivity and respiration of shallow lakes or the epilimnion of deep lakes are calculated from measurements of dissolved oxygen at three times during a 24 hour period -- first at dawn on the first day, second at dusk on the same day, and third at dawn the following day. Thus, it is often called the dawn-dusk-dawn diurnal (diel) method. If samples are taken at representative depths and if the lake is fairly productive, this method is useful for estimating ecosystem primary productivity. This program does not correct for diffusion, although that can be done easily if the diffusion coefficient is measured. Figure 1 shows how the lake productivity and respiration are estimated graphically in this program. For more information on this method, see Mitsch and Kaltenborn (1980).

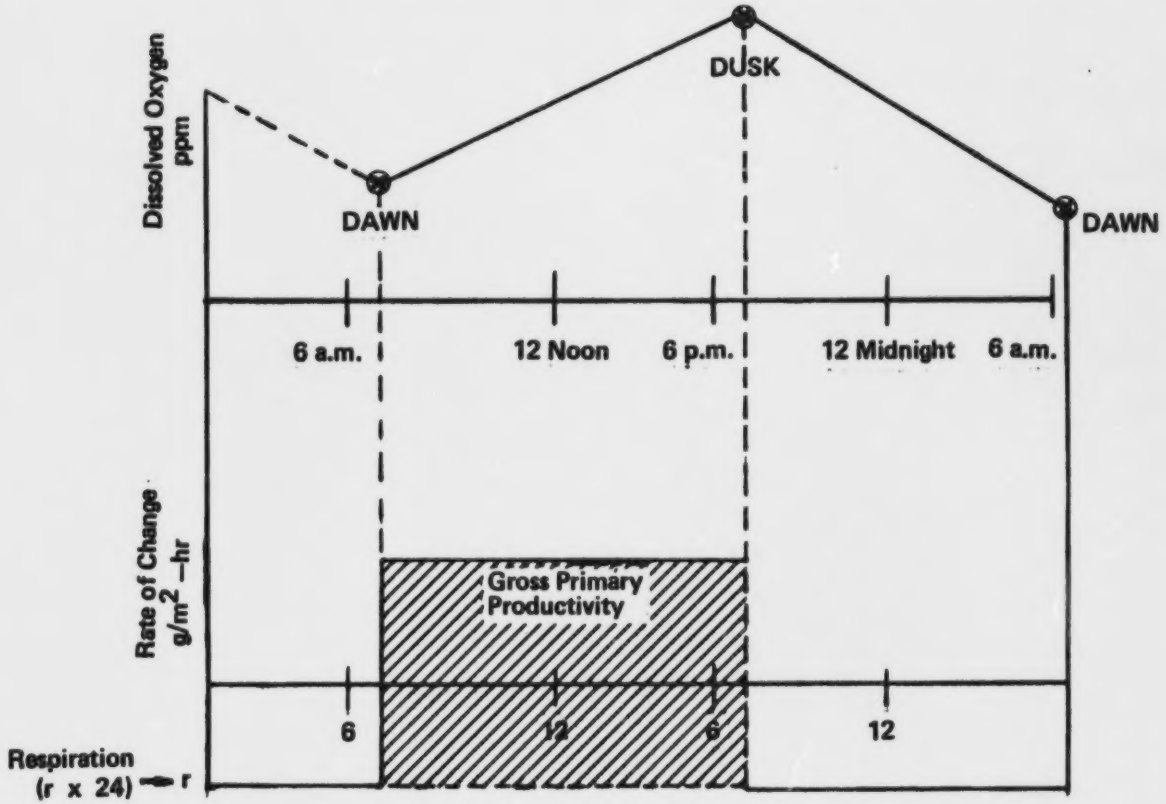


Figure 1. Example of Diurnal Oxygen Curve Method for Calculation of Gross Primary Productivity.

LAKE MORPHOMETRY AND HYDROLOGY

Lowell E. Keup, Criteria and Standards Division, Office of Water, U. S. Environmental Protection Agency, Washington, D.C.

This program enables the user to estimate areas of a lake at different depths, rough volume between two depths, including the entire lake, the shore development factor, and mean depth of the lake. The depth/volume calculations are based on the geometry of a truncated cone where Vt (total volume) = V1 +V2 +V3 ... Vn. Area measurements are calculated by summing the number of line units on the grid intersecting the various depth zones of any lake (Figure 2). All inputs and outputs of this program are in english measurements.

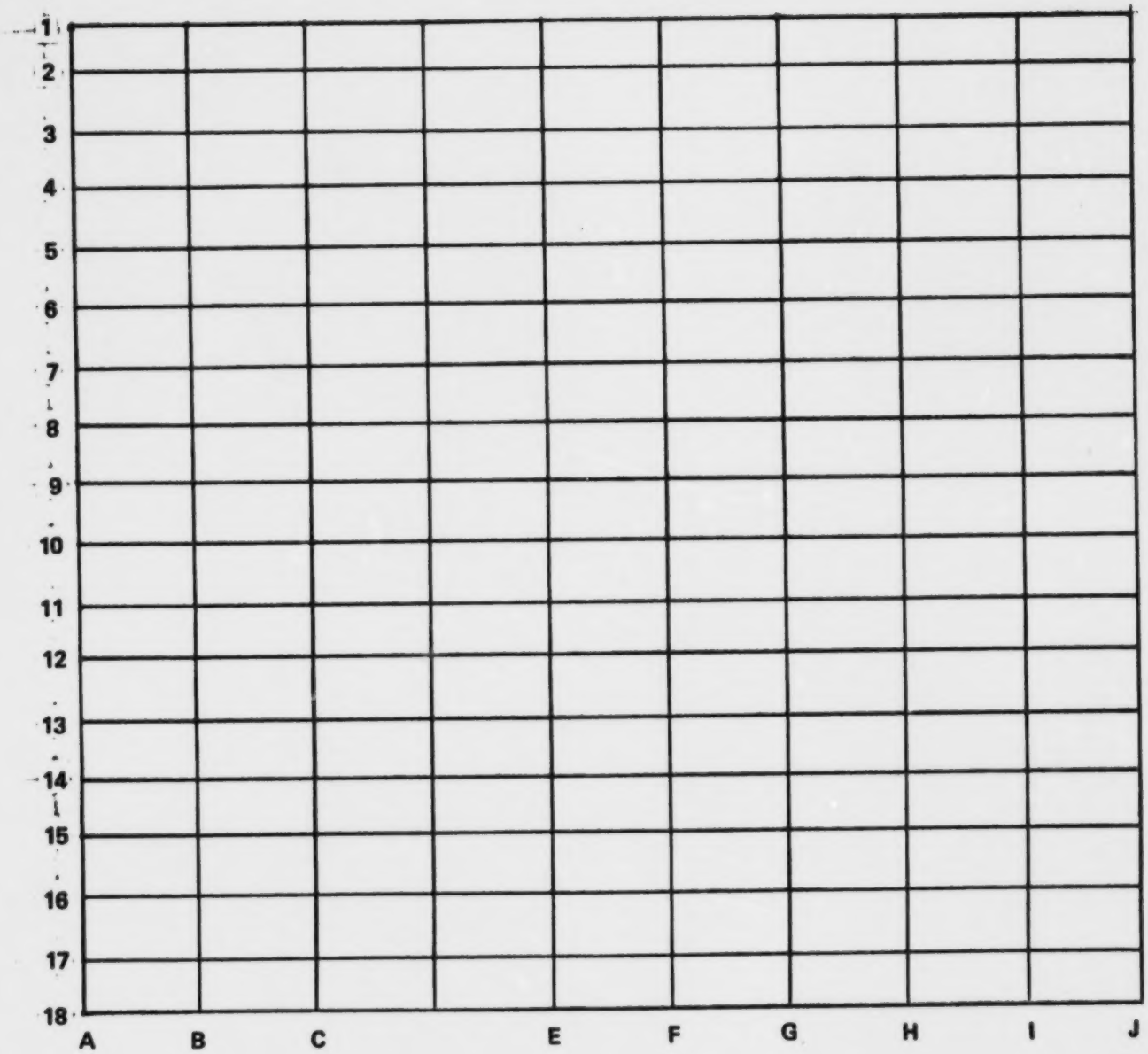
The following information is required to run this program:

1. knowledge and use of Simpson's rule[1] of methods of ordinates (see pp. 88-90, Welch 1948).
2. the length of the shore line (for shore development). This program can be used for lakes with (1) bottom surface area roughly 80% of uniform depth; (2) bottom contour soundings (in feet) referenced from a 10 X 10 areal grid with reference points equidistant (100 data points maximum, See Figure 2).

An example output for lake morphometry and hydrology can be accessed as "Sebastacook.Lake." A printout of the example is shown below.

Area (15% error compared to actual measurement):

```
AREA AT DEPTH 0 FT. IS 157836800 SQ. FT. OR 3623.43434 ACRES
AREA AT DEPTH 10 FT. IS 136139520 SQ. FT. OR 3125.33333 ACRES
AREA AT DEPTH 20 FT. IS 105705600 SQ. FT. OR 2426.66667 ACRES
AREA AT DEPTH 30 FT. IS 22651200 SQ. FT. OR 520 ACRES
AREA AT DEPTH 40 FT. IS 1742400 SQ. FT. OR 40 ACRES
AREA AT DEPTH 50 FT. IS 580800 SQ. FT. OR 13.3333333 ACRES
```


1
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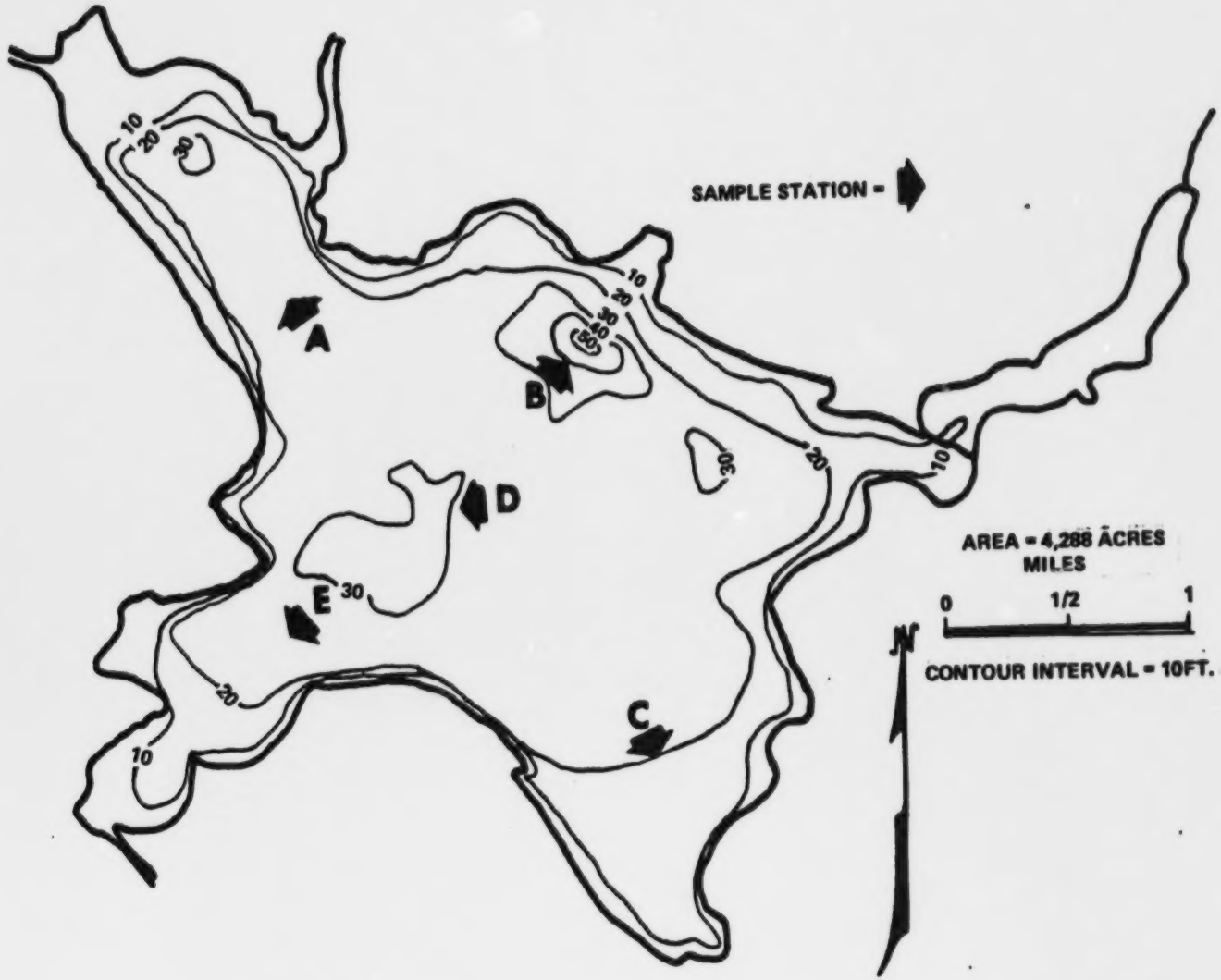

Figure 2. Lake Sebasticook and Sampling Stations

Volume (9% error compared to actual measurement):

VOLUME BETWEEN DEPTHS 0 & 10 IS 1.46854528E+09 CU. FT. or 33713.1608 ACRE FT.
VOLUME BETWEEN DEPTHS 10 & 20 IS 1.20602135E+09 CU. FT. or 27686.4405 ACRE FT.
VOLUME BETWEEN DEPTHS 20 & 30 IS 590963282 CU. FT. or 13566.6502 ACRE FT.
VOLUME BETWEEN DEPTHS 30 & 40 IS 102253042 CU. FT. or 2347.40684 ACRE FT.
VOLUME BETWEEN DEPTHS 40 & 50 IS 11097250.4 CU. FT. or 254.757814 ACRE FT.

TOTAL LAKE VOLUME IS 3.3788802E+09 CU. FT. OR 77568.416 ACRE FT.

THE SHORE DEVELOPMENT FACTOR IS 1.1855641[2]

THE MEAN DEPTH OF THE LAKE IS 21.4074297 FT. (8% error compared to actual measurement).

---

[1] For use of Simpson's rule in this program, if a vertical line intersects the lake more than once at a specified depth, then enter the sum of the distances between the lake borders transected. Enter the sum for the length across the lake at that depth and horizontal position (round to the nearest 10th). Also, if horizontal and vertical coordinates intersect on land, enter a zero.

[2] The shore development calculated for the "Sebastacook.Lake" example is off by an order of magnitude using the grid shown in Figure 2. The value should be closer to 3.0 rather than 1.19 and may have resulted from inconsistencies in counting tributary irregularities.

AQUATIC INSECT IDENTIFICATION

The following key is designed to identify the orders of all stages of aquatic and semiaquatic insects. In most cases, insects found living on the surface or submerged in a body of water are found in this key (after Merritt and Cummins 1978).

WATERSHED ANALYSES

Trophic Condition Index (Brinkhurst 1968)

The T.C.I. was developed by Brinkhurst to ascertain the impacts of nutrient discharges to the St. Lawrence-Great Lakes. Index values ranging from 0 to 2.0 are determined based on tolerance levels of species and the number of individuals within the tolerance categories. See Table 1 for derivation of T.C.I. and other biotic indices contained in this album.

Empirical Biotic Index (Chutter 1972)

Community Diversity Index (EPA 1973)

Diversity Index (EPA 1973)

Index of Simiarity Between Two Samples (Southwood, 1966)

Universal Soil Loss Equation (EPA 1982)

This program calculates the loading of sediments to a body of water from rural areas, defined here as either cropland, pasture, woodland, or a combination of all three. The program uses the universal soil loss equation contained on pp. 170-171, Appendix A.

Sediment Routing Procedure (EPA 1982)

This program, based on the modified soil loss equation, enables the user to predict sediment yields for individual storms on a watershed. The program can be used for large watersheds, provided the soils, topographic, crop management and practice factors are average for the entire watershed.

Table 1. Biological Indices

Index	Formula	Where	Pollutional Classification
Trophic Condition Index (T.C.I.)	$\frac{\Sigma N_1 + 2\Sigma N_2}{\Sigma N_0 + \Sigma N_1 + \Sigma N_2}$	N_0 = # intolerant organisms N_1 = # facultative organisms N_2 = # tolerant organisms	0 = Maximum oligotrophy 2.00 = Maximum eutrophy

Emperical Biotic Index (E.B.I.)	$\frac{\Sigma(a \cdot b)}{N}$	a = # in ith species
		b = quality value (0-10) of ith species
			0-2 = clean H_2O
			2-4 = slightly polluted H_2O
			4-7 = enriched H_2O
			7-10 = polluted H_2O

Community Diversity Index ($\bar{d}$)	$-\sum_{i=1}^{S} (ni/N \cdot \text{Log}_2\ ni/N)$	ni = # individuals in the ith species
		N = total # individuals/ sample
			1.00 = polluted H_2O
			3.00 = clean H_2O

Diversity Index (D)	$\frac{S - 1}{\log N}$	S = total species N = total # individuals	
INDEX OF SIMILARITY (S) BETWEEN TWO SAMPLES	$S = \frac{2C}{A + B}$	A = number of species in sample A B = number of species in sample B C = number of species common to both samples	

Note: Index of dissimilarity = 1 − S.

Phosphorus loading (Dillon and Rigler 1974)

This program enables the user to predict the total annual phosphorus load to a lake based on the Dillon/Rigler Model. The user is prompted for all data requirements.

Commonly Used Units and Conversion Factors:

One mgd (million gallons per day)
= 1.55 cfs (cubic feet per second)
= 3.78 mld (million liters per day)

One cfs
= 0.028 cm/sec (centimeters per second)

Cms/sec (cubic meter per second)
= 0.043 mgd

bg (billion gallons)
= 3.8 million cubic meters

cm (cubic meter)
= 264.2 gallons

Bioassay/Effluent Discharge (APHA, et al., 1981)

This program estimates the rate of effluent discharge presumed safe for aquatic life in streams. LC_{50} values must be available in %, and the stream flow in cubic feet per second (cfs). The application factor is assumed to be 10. Procedures for conducting bioassay tests are given in the 15th edition of "Standard Methods for the Analysis of Water and Waste Water" (APHA, et al., 1981).

Extreme caution should be exercised using this formula and applying the results to site specific situations. LC_{50} values even for the same constituent may differ markedly based on test conditions and kind of test organism. Also, the "Application Factor" in this program is set at "10." This factor has historical significance, but in use, may not be appropriate for all conditions, discharge types and fauna to be protected.

Explanation of Terms:

LC_{50} - Lethal concentration, through graphical extrapolation, at which 50% of the test organisms die within a specified period of time, usually 96 hours.

DV - (Dilution Volume) the total volume or flow of water required to dilute the effluent to the LC_{50}.

QE - (Effluent flow) the volume or flow of the effluent from the source.

QS - The total flow dilution requirement for presumed safety to aquatic life.

Index of Similarity (S) between two samples (Southwood 1966)

This program will enable the user to determine the similarity index (S) of two samples, which is the reciprocal of the Diversity Index (Table 1). A value of (S) near 1.0 indicates distinct similarities between the samples. The Index of Dissimilarity (1-S) will also be displayed.

MIDGE (CHIRONOMIDAE: DIPTERA) IDENTIFICATION

William T. Mason, Jr., Office of Environmental Processes and Effects Research, EPA, Washington, DC

This program facilitates identification of larval, pupal, and adult stages of midge subfamilies. Immature midges are aquatic and are superior indicators of water quality because they are diverse, live on and in a variety of submerged materials and substrates, have widely different species specific water quality preferences, abound in sufficient numbers for quantitative analysis, and some species exhibit world-wide distribution. They occur in all freshwaters and to salinities less than 2 ppt. Consult specific keys cited in EPA (1973) for more definitive identifications.

WATERSHED 3-D

William P. Mason, Frederick, Maryland

"Watershed 3-D" is a "user friendly" program that can be used to formulate and visualize watershed topography and bathymetric configurations for site planning scenarios. Various images representing water, trees, rocks, houses, roads, and wildlife can be superimposed onto a base grid that is developed by the user from a U.S. Geological Survey (USGS) standard topographic relief map or from bathymetric configurations taken from water depth soundings (see Lake Morphometry and Hydrology).

Any printer connected to an interface card that allows a Hi-Res dump for hard copy renditions of the completed plan will suffice. Snapshots of the visual (TV monitor or CRT monitor) can be taken with instant print or 35 mm camera. The user should use a transparent grid as shown in Figure 3. An example use of Watershed 3-D can be accessed after entry to the main program under "Example.Mountain."

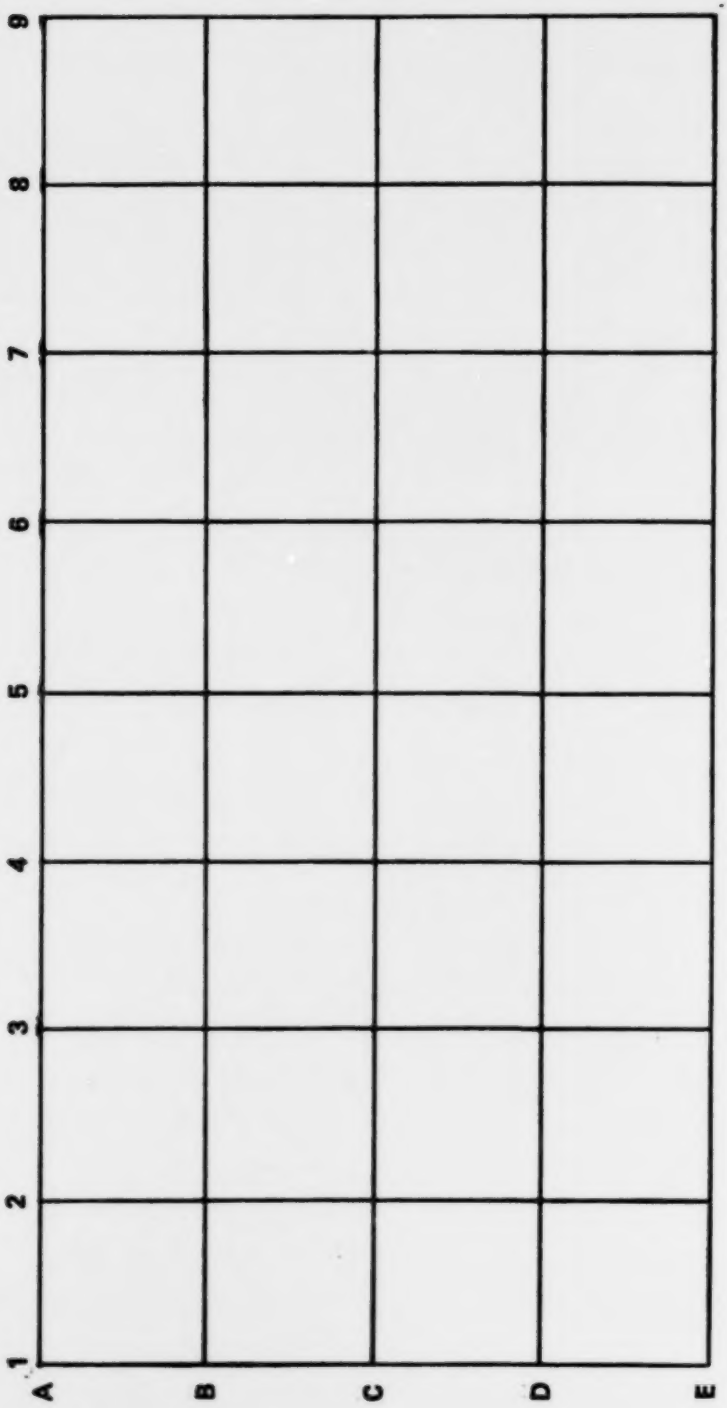

Figure 3. Example Grid for Watershed 3D Program

Instructions for Watershed 3-D

1. The site area is located on a USGS topographic map, e.g., 1:24,000 series.

2. Place the grid overlay sheet (Figure 3) so that point A-1 in transect "A" is in the upper left hand corner of the selected area.

3. Record the elevation (in meters or feet) at the first locator point A-1.

4. Do this for all the remaining points on transect "A" (2-9).

5. At transect "B", record elevations at points 1-9, and continue with transects "C", "D", and "E". Round off all readings to the nearest 50'th foot, e.g., 950; not 951, or the program will not run.

6. You are ready to input the data into the program.

7. From the program catalog, enter the letter designation for "Watershed 3-D", the prompt cursor will appear, then enter "E" and press "Return." The program should "run". Enter the data as prompted and press return after each entry. If an erroneous entry is made, you must start the data entry from the beginning.

8. When you have finished the representation of the topographic or bathymetric map, the editing program will automatically load into the computer.

9. The symbol editing dot is started in the upper left hand corner of the screen. The commands to move the dot are as follows: key "T"-move up; key "G"-move right; key "F"-move left; and key "V"-move down.

10. To place a symbol at a point, place the editing dot over that area, and enter "p". The prompt "put what ?" will be displayed. Now enter the symbol number. The symbols and numbers are as follows: 1-tree, 2-pine tree, 3-bare soil, 4-rock, 5-game, 6-water, 7-livestock, 8-house, and 9-factory. To "draw" a line, enter "l" at the starting point, then go to the desired and point and enter "k". You will then be prompted for a color. Enter "w" and the line will appear, or "b" to erase the line.

11. To erase a symbol place the editing dot on the point when the symbol was initialed and enter "c" and then the appropriate symbol number.

12. To recall the watershed, boot the program and respond "y" to the first question.

13. To save a watershed on a separate initialized data disk, remove the program disk and insert the data disk, then enter "s".

PENNSYLVANIA MODELING UTILITY PACKAGE
Disk 2. Copyright 1983

Gary A. Lake, Pennsylvania Department of Environmental Resources
Bureau of Water Quality Management, Harrisburg, PA.

The computer programs contained herein are experimental and/or research tools. No claims are made or implied as to the accuracy or usability of these programs by the PA DER or EPA. The Commonwealth of Pennsylvania, Department of Environmental Resources, Bureau of Water Quality Management

Catalog[1] for DISK 2 is:

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*A 006 HELLO
*A 007 HELLO.APPLE
*A 007 MENU
*B 034 BANNER1
*A 048 DOSAG
*A 014 K1
*A 006 DIVERSITY.INDEX
*A 009 STRESS
*A 010 K2
*A 007 WLA
*A 010 WLA.MENU
*A 041 WLA.DATA.MGT
*A 018 WLA.RUN
*A 035 WLA.MODEL
*A 013 WLA.REPORT
*B 034 BANNER2
*B 003 CHAIN
*B 002 ZAP
 T 004 WLA.DEMO.DATA4
*A 004 COPYRIGHT.NOTES
 T 002 DOSAG.DEMO.DATA2
*A 014 LEAST.SQUARES

]PR#1  (turns printer "on")
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[1]The user is referred to the separate "Users Guide" for the Pennsylvania "Waste Load Allocation (WLA) Model" Appendix C of this album. Programs not preceded by an "A" can not be accessed directly from the menu.

The Pennsylvania Modeling Utility Package contains seven programs as described below. Each is accessed by responding to a prompt in the menu. All seven programs are Copyright protected by the Commonwealth of Pennsylvania.

Program #1 - D.O. SAG

This version of D.O. SAG is a multi-reach version with graphic and numeric printout capabilities. It is limited to 10 reaches, each divided into 10 subreaches. The hi-res graph has proportional spacing on the X-axis, and the Y-axis (D.O. mg/l) is labeled at the 5 and 6 mg/l levels to assist in spotting possible violations[1]. File storage and retrieval is permitted.

The model is a two-stage, Streeter-Phelps model with BOD and NH_3 being used simultaneously, i.e., no delay in NH_3 oxidation. This version does not contain any provisions for overall removal rate of BOD which can provide for settling or resuspension. Also missing are lateral inflows, respiration-photosynthesis, and benthic demand. These features will be added as soon as possbile. The BOD and NH_3 values that appear on input and output are BOD-5 and NH_3-N. Although the model works in ultimate demand, the conversions are made internally by multiplying these values by 1.5 and 4.57, respectively.

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[1] Editor's Note: The established levels of "standards" depicted graphically in Disk 2 are based on Pennsylvania criteria and standards.

Program #2 - Wasteload Allocation Model

This system of programs is released for FIELD TESTING ONLY. This means that the logic tests performed to converge to a solution are subject to change based on the reaction of users in the field. This system has a separate User Manual (Appendix C) to explain its options. Briefly, the programs will perform data management to and from disk, will perform a D.O. SAG type of analysis on the data, and perform a wasteload allocation analysis on the data.

The analysis methods include (1) equal effluent concentration and (2) equal percent removal. The user will be prompted for selection of one of four subprograms. However, data must first be entered in option 1 (Data Management) before the other three subprograms will run.

Program #3 - Reaeration Formulae

This program will calculate reaeration rates (Kr or K2) from physical stream data such as slope, depth, etc. The equations used are taken from the DER-EPA Simplified Method. The program has an option to display the equations used.

Program #4 - Carbonaceous Decay Rates

This program will calculate a carbonaceous decay rate using in-stream CBOD and travel time data. The calculations use a linear regression (least squares) procedure and calculate Kc in units of e/Day.

Program #5 - Diversity Index[1]

This program will calculate an index (0 to 4) which represents the diversity of the aquatic organisms in a series of stream reaches. The user

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[1]Editor's Note: This program provides the same answer as the "Community Diversity Index" given under "Biotic Indices" in Disk 1. Program 5 of the PA-DER package is duplicated due to copyright protection for Disk 2.

enters the number of stations followed by the number of various taxa at each station. The program will request data until the number of taxa is entered as zero.

Program #6 - Stress Recovery Index

The Stress Recovery program may be used to calculate an index which will measure the likelihood of a stream's recovery from a polluted state. The input data consists of eight questions relating to such items as the existance of a management agency, or the nearness of other aquatic organisms, etc.

Program #7 - Linear Regression (Base 10)/Least Squares

This program will perform a least-squares analysis on two-dimensional base-10 data, e.g., ordinary X-Y data. The regression equation will be calculated in the form of Y=mX+b. Also included is an option to edit the data.

General Reference, Stream Load Equations:

$$\text{Flow(mgd)} = \frac{\text{loading (kg/day)}}{\text{conc. (mg/l)} \cdot 3.785}$$

or

$$\text{Loading (kg/day)} = \text{conc. (mg/l)} \cdot \text{flow (mgd)} \cdot 3.785$$

A. Ultimate Oxygen Demand (UOD) in mg/l = $1.5 \cdot BOD_5 + 4.57 \cdot$ Total Kjeldahl Nitrogen (TKN)

B. Conversion equation for BOD_5 (mg/l) to lbs/day loading

$$\frac{BOD_5 \text{ (mg/l)} \cdot 8.34 \text{ lbs}}{\text{Flow (mgd)}} = \text{lbs/day}$$

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Appendix A

SUPPORT DOCUMENTS FOR UNIVERSAL SOIL LOSS EQUATION CALCULATIONS

APPENDIX A

CHAPTER 3
WASTE LOADING CALCULATIONS

3.1 INTRODUCTION

This chapter outlines basic procedures that can be used to generate estimates of diffuse (nonpoint) and point source loads. Loading functions for the following pollutants will be considered for nonpoint sources:

- Sediment
- Nutrients (phosphorus and nitrogen)
- Organic matter
- Salinity in irrigation return flow
- Toxic organic pollutants
- Metals

Both cultivated and noncultivated agricultural land as well as urban areas are addressed in this report. For agricultural lands, long term sediment loads are calculated with the Universal Soil Loss Equation (USLE). This method has been adopted for a number of reasons, principal among them being the large data base that exists for the terms in the USLE. The modified USLE is presented as a method for estimating single event conventional pollutant loads. The loading of both nutrients and organic matter can be quantitatively related to sediment loading. Thus, the discussion of nutrients and organic matter logically follows the sediment loading calculations. These selected water quality parameters were chosen for inclusion in this report because they represent commonly occurring problems of major concern to planners.

Salinity in irrigation return flow is important in many areas in the arid western states. Considerable data are included in this report especially for the Colorado River basin and the irrigated regions in California (Section 3.2.8). Procedures are included for determining electrical conductivity and sodium adsorption ratio (SAR).

For urban areas two procedures are presented; the URS Urban Water Quality Management procedure and the SWMM Level One Screening procedure. In the former, solids loading rates are first calculated and then the loading rates of other pollutants are related to them. Pollutants considered in this section include BOD, phosphorus, nitrogen, coliforms, and heavy metals. In the SWMM procedure separate and combined sewers are considered as well as street sweeping efficiency. Single event procedures are also provided for urban areas.

Next, typical point source pollutant loads for municipal and industrial discharges are discussed. Whenever possible, however, local data should always be used, if available, in lieu of the "typical" loadings given here.

Within each major section a subsection on toxic organic pollutants is included. These sections cover the various ways in which toxicants accumulate on watershed surfaces and provide procedures to estimate washoff of toxicants in the sediment and water phases.

Each of the major divisions on nonpoint source calculations (agricultural and urban areas) in this chapter is essentially independent of every other. Accordingly, they can be used in any order. Within each section, the calculations performed can be used in two different ways. First, the magnitude of loadings can be compared for various alternatives (e.g., different land use schemes) to ascertain the significance of the changes. Second, the loadings can be used in calculations presented in Chapter 4 to assess the water quality impacts of nonpoint source pollutants on rivers and streams. These data can then be used to determine input of nonpoint source pollutants to impoundments (Chapter 5) and estuaries (Chapter 6), as appropriate.

In writing this chapter the following sources have been heavily and freely drawn upon: "Loading Functions for Assessment of Water Pollution from Nonpoint Source (McElroy et al., 1976), "Water Quality Management Planning for Urban Runoff" (Amy, et al., 1974), "Storm Water Management Model Level I, Preliminary Screening Procedures" (Heaney, et al., 1976), "Predicting Rainfall Erosion Losses: A Guide to Conservation Planning" (Wischmeier and Smith, 1978) and "A Mathematical Model for Estimating

Pesticide Losses in Runoff" (Haith, 1980). Users should refer to these references for further details concerning the methodologies.

3.2 NONURBAN NONPOINT SOURCE LOADS

3.2.1 Annual Sediment Loads

Sediment loading is defined in this report as the quantity of soil material that is eroded and transported into the watercourse. Sediment loading is dependent on (a) on-site erosion, and (b) delivery, or the ability of runoff to carry the eroded material into the receiving waters.

The sediment loading function is based on the mechanisms of gross erosion and sediment delivery. The Universal Soil Loss Equation (Wischmeier and Smith, 1965) has been chosen to predict on-site surface (including sheet and rill) erosion, for the following reasons:

1. This equation is applicable to a wide variety of land uses and climatic conditions.

2. Data have been collected nationwide for factors included in the equation.

The sediment loading function has the form:

$$Y(S)_E = \sum_{i=1}^{n} [A_i \cdot (R \cdot K \cdot L \cdot S \cdot C \cdot P)_i S_d] \qquad \text{(III-1)}$$

where

$Y(S)_E$ = sediment loading from surface erosion, (tons/year, tonnes/year)

n = number of subareas in the area

A_i = acreage of subarea i, (acres, ha)

R = the rainfall factor, expressing the erosion potential of average annual rainfall in the locality.

K = the soil-erodibility factor, commonly expressed in tons per acre per R unit

L = the slope-length factor, dimensionless ratio

S = the slope-steepness factor, dimensionless ratio

C = the cover factor, dimensionless ratio

P = the erosion control practice factor, dimensionless ratio and

S_d = the sediment delivery ratio, dimensionless.

Equation III-1 can be used to predict sediment loading resulting from sheet and rill erosion from cultivated and non-cultivated lands. Parameter values for silviculture, construction, and mining are less well documented than for agriculture, however. The user will thus find it relatively easy to use Equation III-1 for agriculture, and substantially more difficult for other sources. The equation does not predict sediment contributions from gully erosion, streambank erosion, or mass soil movement.

Estimation of surface erosion should be made for each relatively homogeneous land-use type. For a given land-use type, if 90 percent or more of the area is made up of one soil type, one may calculate soil loss for each soil type that makes up at least 10 percent of the land use, and then obtain a weighted average for the entire land-use area (U.S. Dept. of Agriculture, 1974). There is no limitation on how finely the watershed can be broken down into subwatersheds. This determination should be made based on information density, time and monetary restrictions, and level of accuracy desired in the results. Figure III-1 is a flow diagram showing the usage of Equation III-1 for predicting annual average sediment loads.

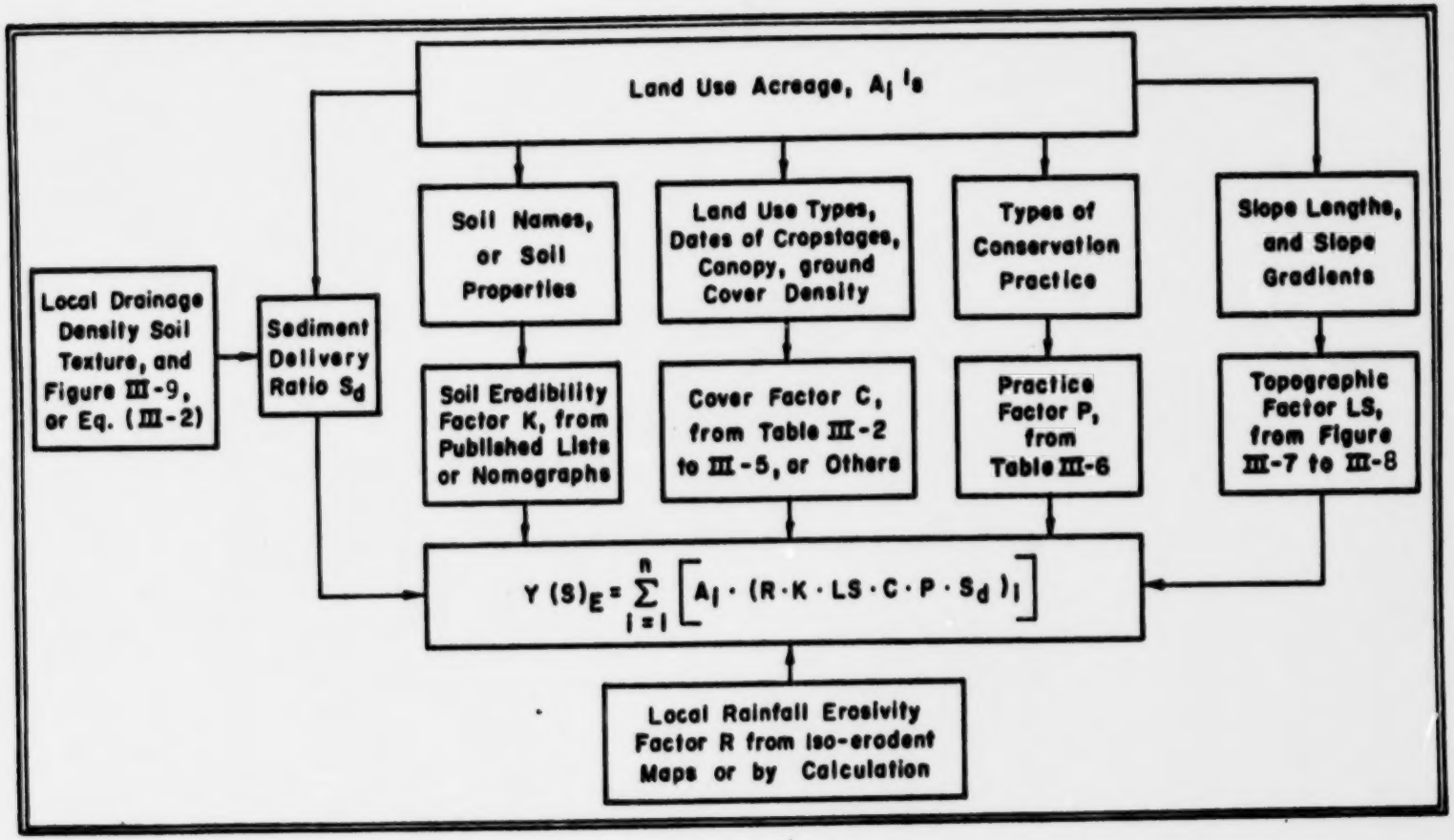
Land Use Acreage, A_i's
Soil Names, or Soil Properties
Land Use Types, Dates of Cropstages, Canopy, ground Cover Density
Types of Conservation Practice
Slope Lengths, and Slope Gradients
Local Drainage Density Soil Texture, and Figure III-9, or Eq. (III-2)
Sediment Delivery Ratio S_d
Soil Erodibility Factor K, from Published Lists or Nomographs
Cover Factor C, from Table III-2 to III-5, or Others
Practice Factor P, from Table III-6
Topographic Factor LS, from Figure III-7 to III-8
$Y(S)_E = \sum_{i=1}^{n} \left[A_i \cdot (R \cdot K \cdot LS \cdot C \cdot P \cdot S_d)_i \right]$
Local Rainfall Erosivity Factor R from iso-erodent Maps or by Calculation

FIGURE III-1 FLOW DIAGRAM FOR CALCULATING SEDIMENT LOADING FROM SURFACE EROSION

3.2.1.1 Data Requirements

The following should be obtained:

- total area, and land use acres in the area: cropland, pastureland, and woodland, etc.
- soil characteristic information (e.g. soil texture) for each land use.
- canopy and ground cover condition for each land use.
- good topographic maps
- the type and extent of conservation practices.

3.2.1.2 Determination of USLE Factors

3.2.1.2.1 The Rainfall Factor (R)

R is a factor expressing the erosion potential of precipitation in a locality. It is also called index of erosivity, erosion index, etc. It is the summation of the individual storm products of the kinetic energy of rainfall (denoted by E), and the maximum 30 minute rainfall intensity (denoted by I) for all significant storms within the period under consideration. The product EI reflects the combined potential of raindrop impact and runoff turbulence to transport dislodged soil particles from the site (Wischmeier and Smith, 1965).

Values of average annual rainfall-erosivity index, R, are shown in Figure III-2 for the continental U.S. and Figure III-3 for islands of Hawaii. On these maps, the lines joining points with the same erosion index value are called isoerodents. Points lying between the indicated isoerodents may be approximated by linear interpolation.

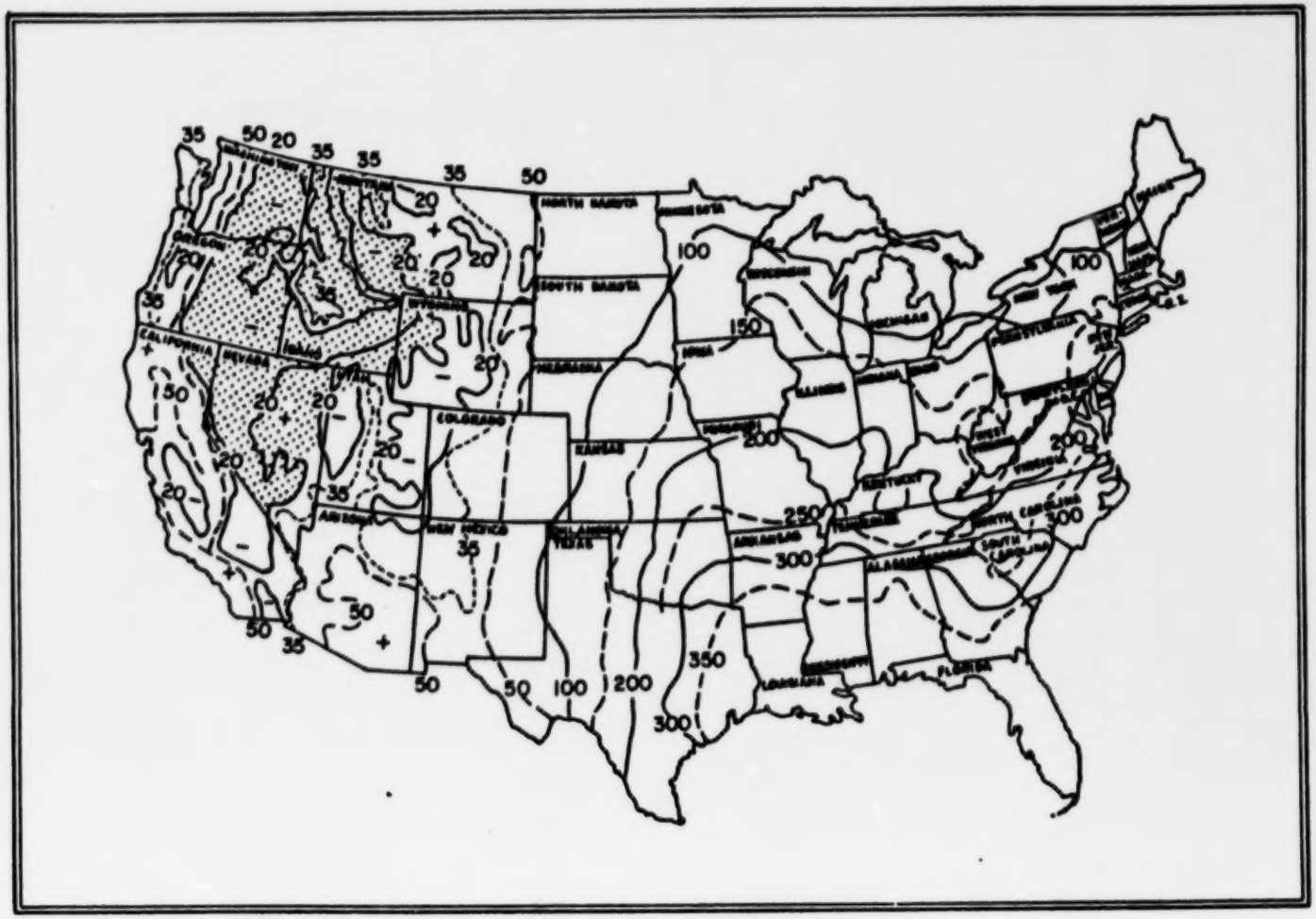

FIGURE III-2 AVERAGE ANNUAL VALUES OF THE RAINFALL-EROSIVITY FACTOR, R (EPA, 1975)

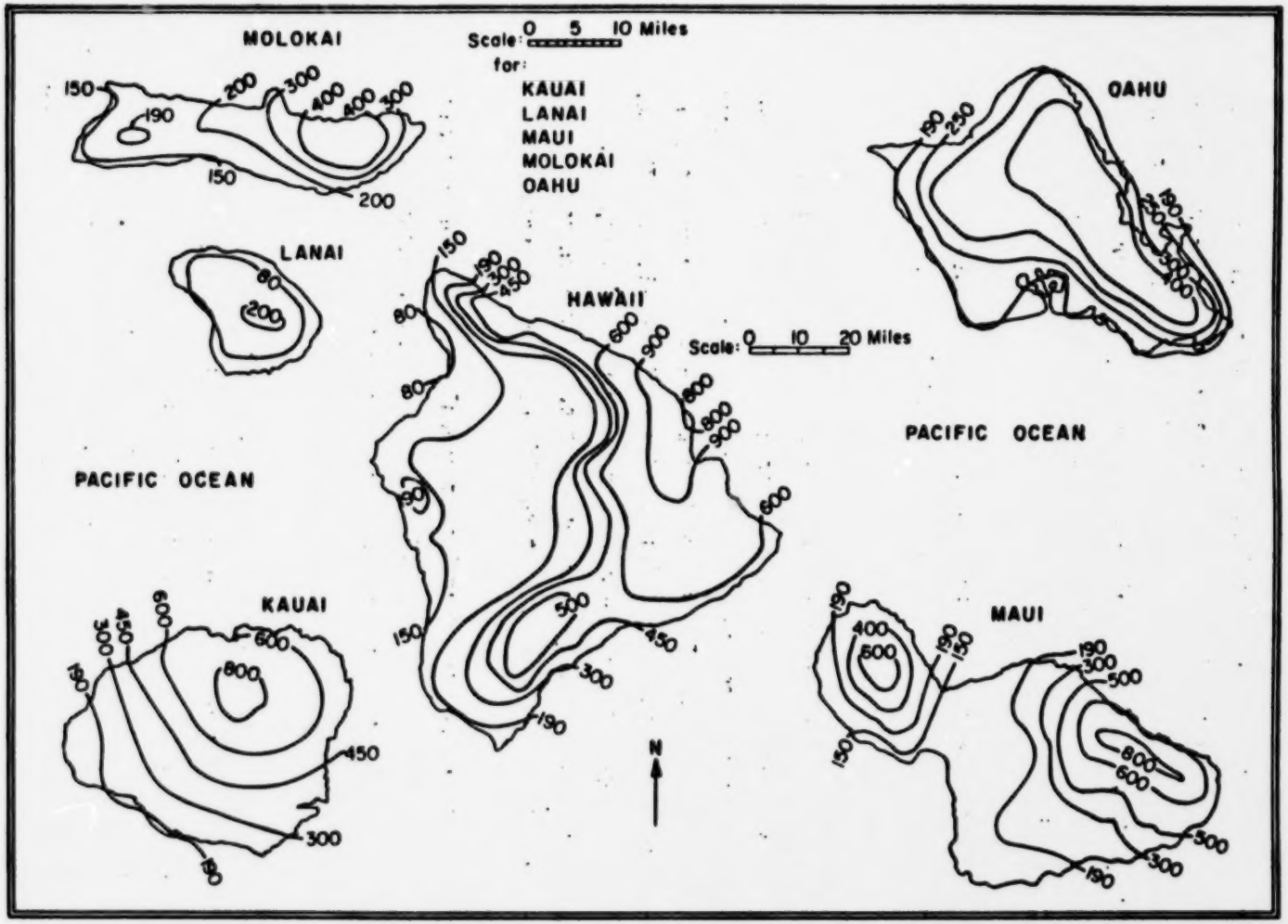

FIGURE III-3 MEAN ANNUAL VALUES OF EROSION INDEX FOR HAWAII (U.S.D.A., 1974)

Interpolation for values of R factors in the mountainous areas, particularly those west of the 104th meridian may not be appropriate because of the sporadic rainfall pattern. Values of the erosion index at specific areas can be computed from local recording rain gage records with the help of a rainfall-energy table and the computation procedure presented by Wischmeier and Smith (1978).

The USDA has recommended that 350 be the maximum used in the Gulf and southeastern states, shown in Figure III-2, until further research can validate values higher than 350.

In the northwestern United States, runoff from snowmelt contributes significantly to surface erosion. The annual index of R for some portions of this region is the combined effect of rainfall and snowmelt designated by R_r and R_s, respectively. The snowmelt factor (R_s) is important in Areas A-1, B-1, and C on Figure III-4 (also refer to Table III-1). The map values in the shaded region of the Northwest (see Figure III-2) represent values for the rainfall effect (R_r) only, and must be added with appropriate R_s values to account for the effect of runoff from thaw and snowmelt.

Interim procedures for calculating annual R values, which include both R_r and R_s, for the northwestern U.S. are described in Conservation Agronomy Technical Note No. 32, USDA/SCS, Portland, Oregon (1974), and are briefly presented below.

The annual R factor is obtained by using as a base the two year, six hour rainfall (2-6 rainfall). Relationships between R_r and 2-6 rainfall vary to conform to specific local climatic characteristics. These relationships are designated as Type I, Type IA, and Type II, and are shown in Figure III-5. Specific areas applicable to these curves are shown in Figure III-6. Type I curve is for the central valley and coastal mountains and valleys of southern California. Type IA curve applies to the coastal side of the Cascades in Oregon and Washington, the coastal side of the Sierra Nevada Mountains in northern California, and the coastal regions of Alaska. Type II curve applies to the remainder of the region. For 2-6 rainfall data, refer to Technical Paper No. 40, U.S. Department of Commerce,

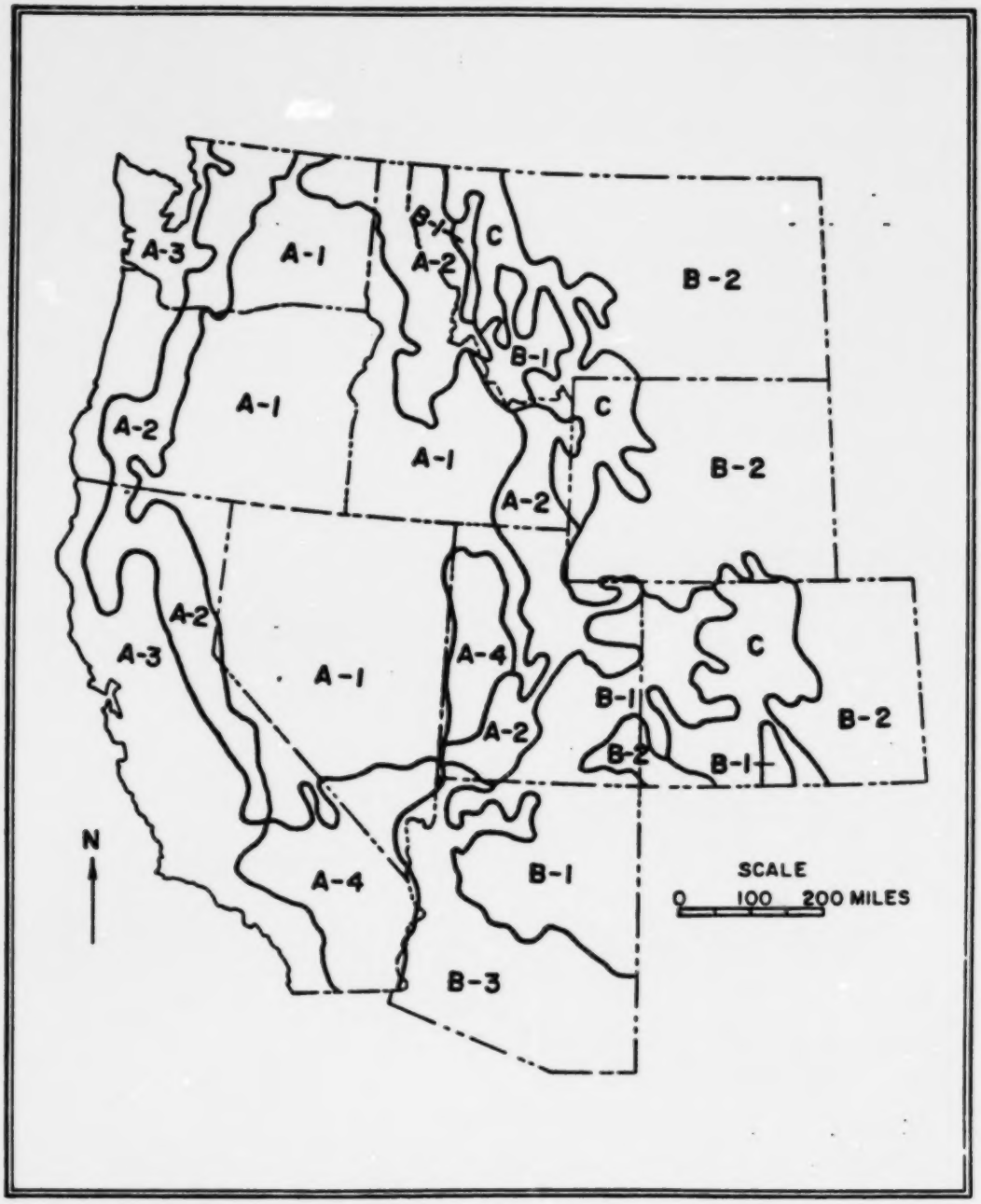

FIGURE III-4 SOIL MOISTURE-SOIL TEMPERATURE REGIMES OF THE WESTERN UNITED STATES (U.S.D.A., 1974)

TABLE III-1

APPLICABILITY OF R_r AND R_s FACTORS IN THE AREAS WEST OF THE ROCKY MOUNTAINS (U.S. DEPT. OF AGRICULTURE, 1974a)

Areas (see Figure III-4)	Typical Locations	R_r	R_s
A-1	Washington, Idaho, Nevada, California, western Utah	X[a]	X
A-2	Cascades, Sierra, Tetons of Idaho, Wasatch Mountains	X	-[b]
A-3	West of Cascades, San Joaquin Valley, west of Sierras	X	-
A-4	Areas of southern California, east of Santa Anas, southern Nevada, intermountain Nevada, Salt Lake area, Utah	X	-
B-1	Western Montana, Colorado, eastern Utah, high elevations of Arizona	X	X
B-2	Great plains area of eastern Montana, Wyoming, Colorado (includes gently sloping mesas and upland at lower elevations of Monticello, Utah area)	X	-
C	Rainfall during summer is high; high elevations	X	X

a/ X needed

b/ - not needed

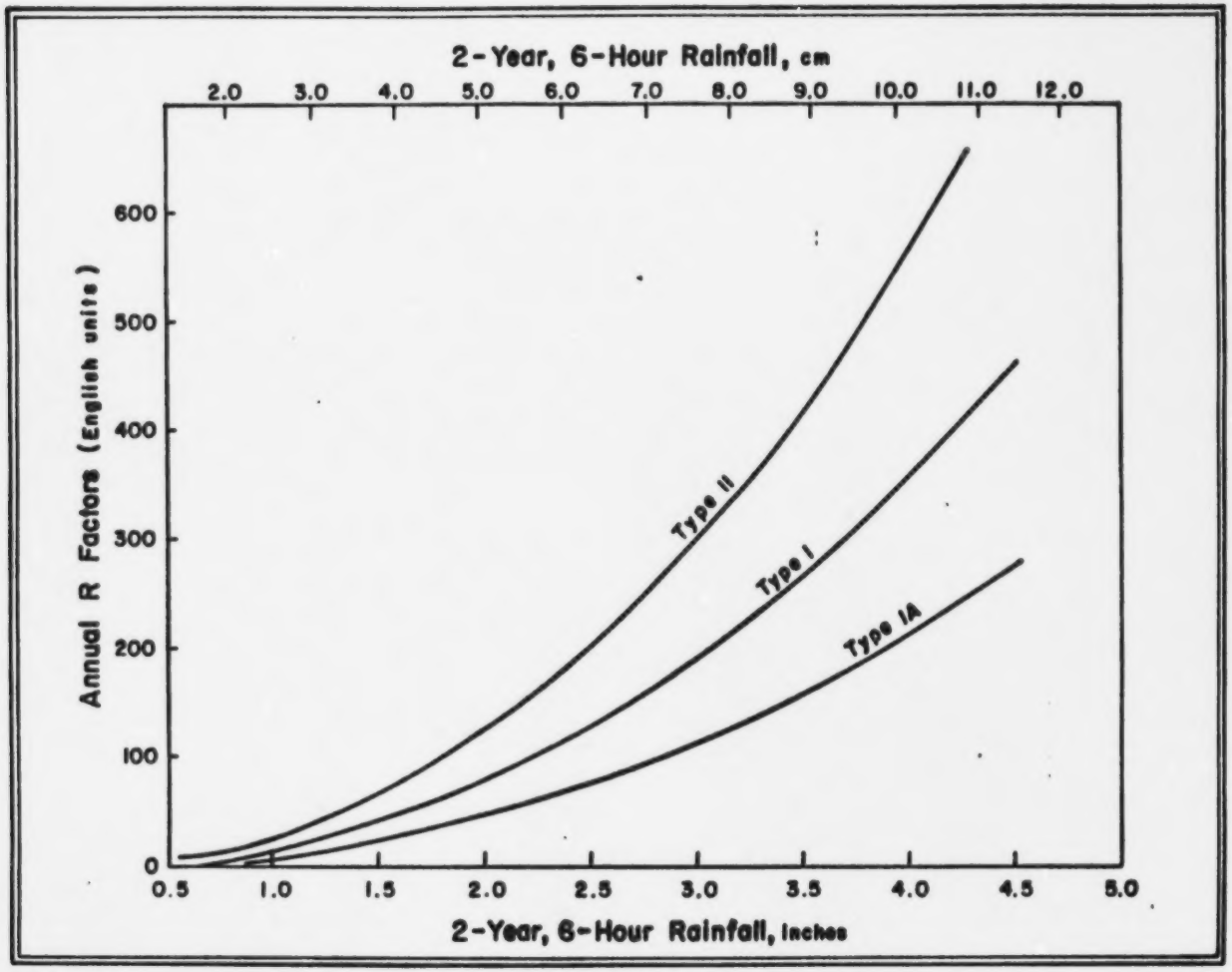

FIGURE III-5 RELATIONSHIPS BETWEEN ANNUAL AVERAGE RAINFALL EROSIVITY INDEX AND THE 2-YEAR, 6 HOUR RAINFALL DEPTH FOR 3 RAINFALL TYPES IN WESTERN U.S. (U.S.D.A., 1974)

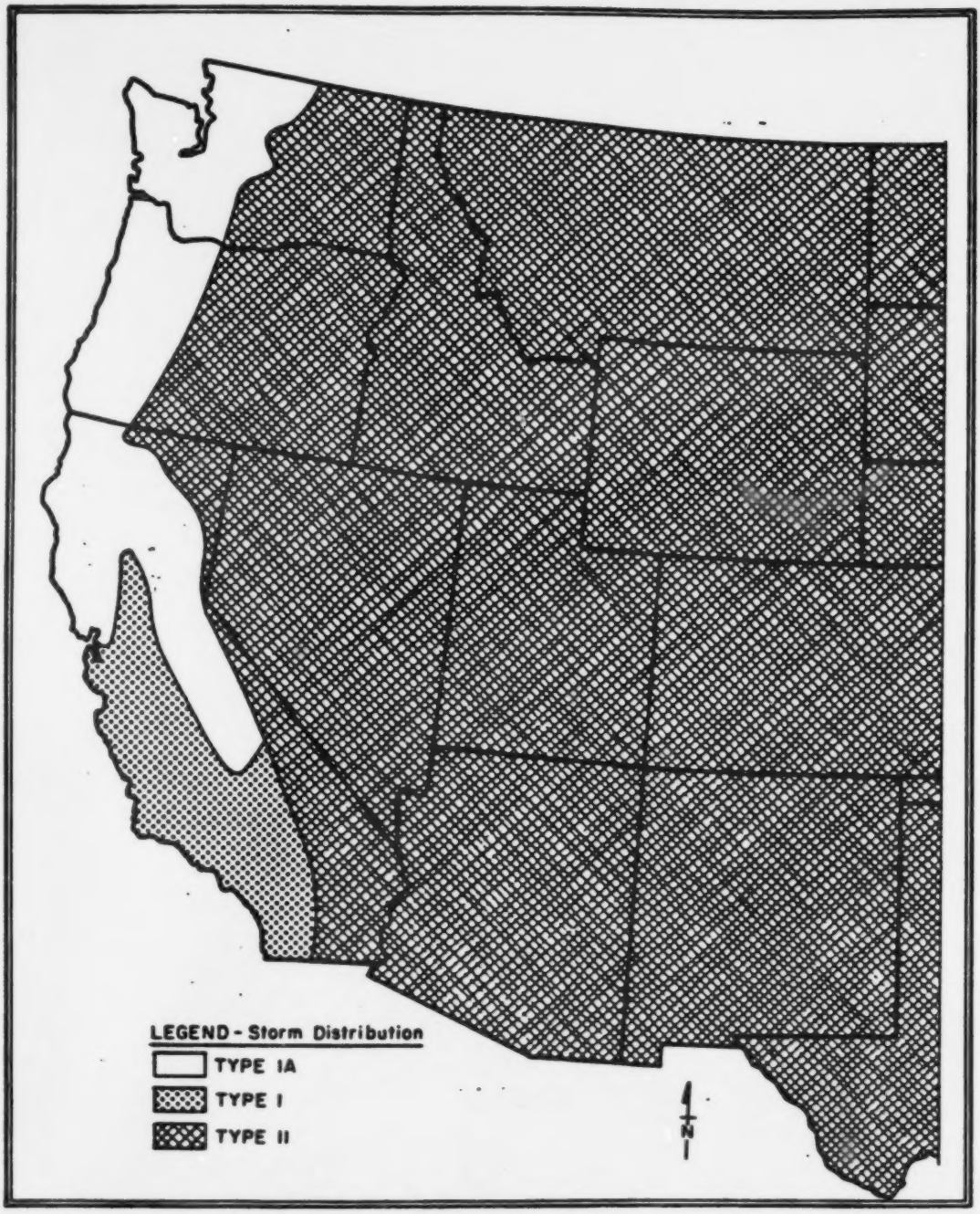

FIGURE III-6 STORM DISTRIBUTION REGIONS IN WESTERN U.S. (U.S.D.A., 1974)

Weather Bureau, Washington, D.C. (1961), or other suitable rainfall frequency analysis reports.

To obtain the annual R_s factor for a given location, obtain the average annual total precipitation by snowfall (in inches of water depth) and multiply it by the constant 1.5.

There are numerous sources of snowfall data for the United States. Some of the major sources are:

- The 1941 Yearbook of Agriculture, USDA, Washington, D.C.,
- "Climates of the States," Water Information Center, Inc., Port Washington, New York (1974), and
- Data resulting from the Western Federal-State-Private Cooperative Snow Surveys, coordinated by SCS/USDA, Portland, Oregon.

Data on snow density is necessary to convert depth of snow to depth of meltwater. Snow at the time of fall may have a density as low as 0.01 and as high as 0.15 g/ml. The average snow density for the United States is taken to be 0.10 (Garstka, 1964). If snowfall is recorded as inches of precipitation, no conversion is required.

The monthly distribution of the erosion index for the 37 states east of the Rocky Mountains has been reported in USDA-ARS Agriculture Handbook No. 282 (Wischmeier and Smith, 1965). Average monthly erosion index values are expressed as percentages of average annual values and plotted cumulatively against time in Appendix A.

The monthly distribution of erosion index for the islands of Hawaii also has been developed (U.S. Dept. of Agriculture, 1974b). These curves are shown in Appendix A. If monthly or seasonal sediment yields are required the annual R value can be factored using the percentages from these figures.

For the areas west of the Rockies in the continental United States, the monthly distribution of erosion index R is the summation of R_r and R_s. Where R_s values are not needed, the R and R_r curves are the same.

The R factor in equation III-1 can be expressed in metric units ((hundreds of metric tons/ha-cm) multiplied by (maximum 30-minute intensity, cm/hr)) by multiplying the English R values by 1.735.

3.2.1.2.2 The Soil-Erodibility Factor (K)

K factor is a quantitative measure of the rate at which a soil will erode, expressed as the soil loss (tons) per acre per unit of R, for a plot with 9 percent slope, 72.6 ft. long under continuous cultivated fallow. K factors for topsoils, as well as subsoils, for most soil series have been developed. Values of K for soils studied thus far vary from 0.12 to 0.70 tons/acre per unit R. Values can usually be obtained from the regional or state offices of the Soil Conservation Service.

K values of soils can also be predicted from soil properties. In Appendix B of this report, two methods are presented from which K values may be determined for topsoils and subsoils when the governing soil properties are known. The factor for conversion of K in English units to metric-tons per hectare per metric R unit is 1.292 (Wischmeier, 1972).

3.2.1.2.3 The Topographic Factor (LS)

Soil loss is affected by both length (L) and steepness of slope (S). These factors affect the capability of runoff to detach and transport soil material.

The slope length factor is the ratio of soil loss from a specific length of slope to that length (72.6 ft) specified for the K factor in the USLE. Slope length is defined as the distance from the point of origin of overland flow to either of the following: the point where the slope decreases to the extent that deposition begins or the point where runoff

enters a well-defined channel. Slope length can be determined accurately by on-site inspection of a field, or by measurements from topographic maps. When the land is terraced, the terrace spacing should be used.

The slope gradient or percent slope factor is the ratio of soil loss from a specific percent slope to that slope (9 percent) specified for the K value in the USLE. A 9 percent slope has a factor value of 1. Slope data may be obtained from topographic maps, engineering or land level surveys, and other sources. A widely used method is to estimate slope from soil survey maps in which the soils have been mapped by slope range.

The slope length (L) and slope gradient (S) are usually combined in the USLE into a single dimensionless topographic factor, LS, which can be evaluated using a slope-effect chart.

The slope-effect chart in Figure III-7 is designed for the following areas shown in Figure III-4: A-1 in Washington, Oregon, and Idaho; and all of A-3 (U.S. Dept. of Agriculture, 1974a). For the remainder of the U.S., the slope-effect chart, Figure III-8, is to be used (U.S. Dept. of Agriculture, 1974a).

Slope-effect charts in Figure III-7 and III-8 can be used when uniform slopes are assumed. The following steps are to be used for obtaining LS values from these charts:

1. Enter the chart on the horizontal axis with the appropriate value of slope length.

2. Follow the vertical line for that slope length to where it intersects the curve for the appropriate percent slope.

3. Read across the point of intersection to the vertical axis. The number on the vertical axis is the LS value.

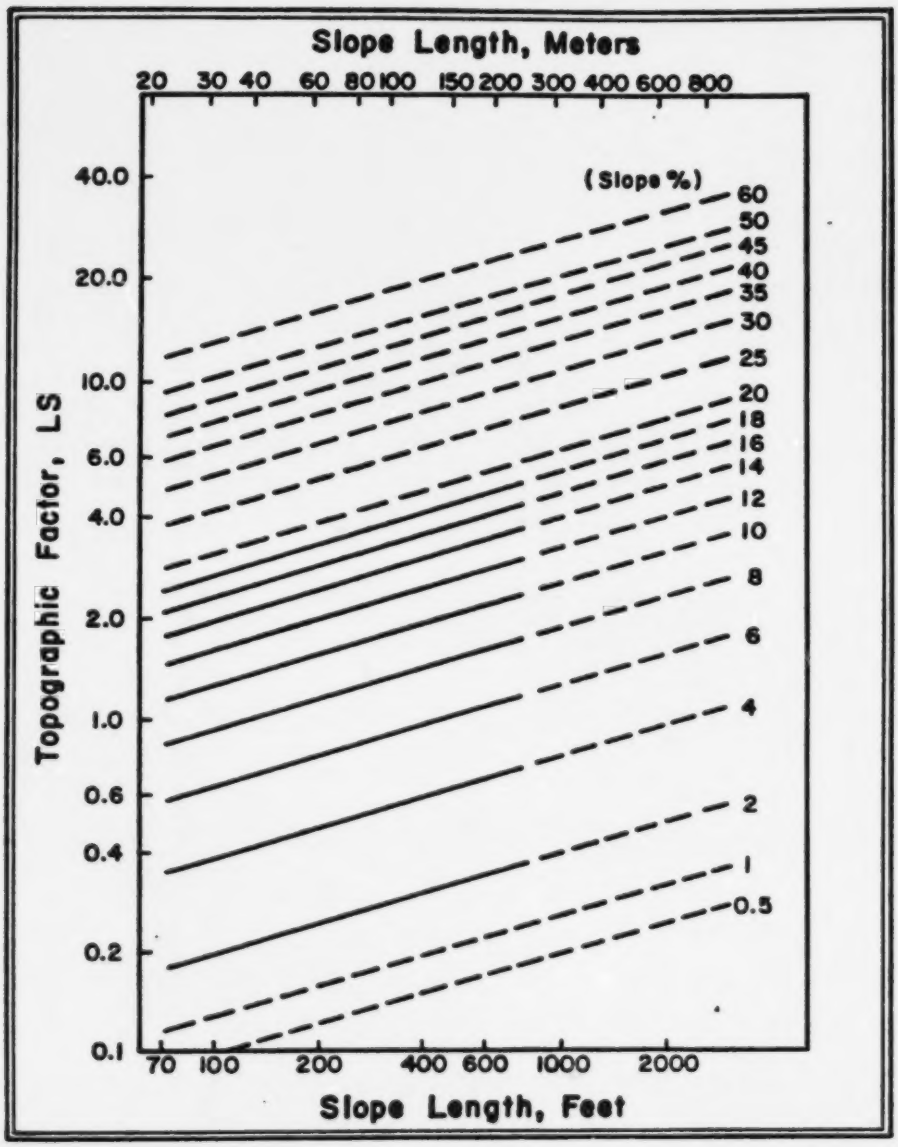

FIGURE III-7 SLOPE EFFECT CHART APPLICABLE TO AREAS A-1 IN WASHINGTON, OREGON, AND IDAHO AND ALL OF A-3 A,B/ (U.S. DEPT. OF AGRICULTURE, 1974)

A/ SEE FIGURE III-4.

B/ DASHED LINES ARE EXTENSIONS OF LS FORMULAE BEYOND VALUES TESTED IN STUDIES.

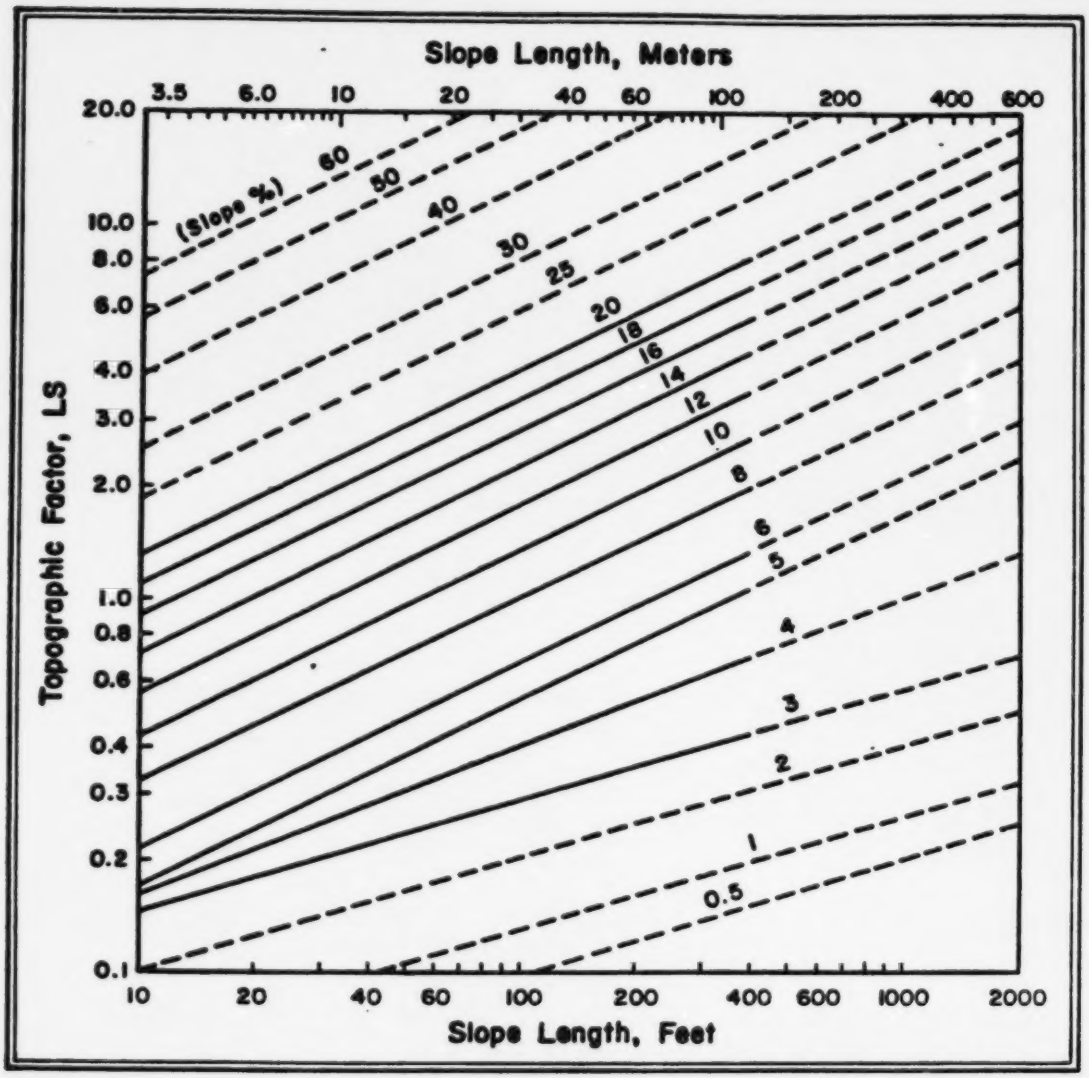

FIGURE III-8 SLOPE--EFFECT CHART FOR AREAS WHERE FIGURE III-7 IS NOT APPLICABLE A/ (U.S. DEPT. OF AGRICULTURE)

A/ THE DASHED LINES REPRESENT ESTIMATES FOR SLOPE DIMENSIONS BEYOND THE RANGE OF LENGTHS AND STEEPNESSES FOR WHICH DATA ARE AVAILABLE.

3.2.1.2.4 The Cover Management Factor (C)

In the USLE, the factor C represents the ratio of soil qualtity eroded from land that is cropped or treated under a specified condition to that which is eroded from clean-tilled fallow under identical slope and rainfall conditions. C ranges in value from near zero for excellent sod or a well-developed forest to 1.0 for continuous fallow, construction areas, or other extensively disturbed soil.

Values of factor C for croplands are highly variable with planting dates, type of vegetative cover, seeding method, soil tillage, disposition of residues, and general management level. Generalized C values for various types of crop management systems are listed in Table III-2. The reader is advised to consult with state conservation agronomists of SCS for appropriate C values for crops in the local area. The reader is also referred to USDA-ARS Agriculture Handbook No. 537 (Wischmeier and Smith, 1978) for a listing of approximated C values for various crops at each crop stage, as well as a working table for derivation of average C value for periods of crop rotation.

C values typical of permanent pasture, range, and idle lands, with varying cover and canopy conditions, are given in Table III-3. These values were developed by Wischmeier (1972). Wischmeier (1972) has also estimated C values for some woodland situations (Table III-4).

For urban and road areas, as well as construction sites, the factor C represents the effect of land cover or treatment that may be used to protect soil from being eroded. Table III-5 (Water Resources Administration, 1973) lists values of the C factors for various soil covers and treatments.

3.2.1.2.5 The Practice Factor (P)

The factor P accounts for control practices that reduce the erosion potential of runoff by their influence on drainage patterns, runoff concentration, and runoff velocity.

TABLE III-2

GENERALIZED VALUES OF THE COVER AND MANAGEMENT FACTOR, C, IN THE 37 STATES EAST OF THE ROCKY MOUNTAINS[1]

Line no.	Crop, rotation, and management[3]	Productivity level[2]	
		High	Mod.
		C value	
	Base value: continuous fallow, tilled up and down slope	1.00	1.00
	CORN		
1	C, RdR, fall TP, conv (1)	0.54	0.62
2	C, RdR, spring TP, conv (1)	.50	.59
3	C, RdL, fall TP, conv (1)	.42	.52
4	C, RdR, wc seeding, spring TP, conv (1)	.40	.49
5	C, RdL, standing, spring TP, conv (1)	.38	.48
6	C, fall shred stalks, spring TP, conv (1)	.35	.44
7	C(silage)-W(RdL, fall TP) (2)	.31	.35
8	C, RdL, fall chisel, spring disk, 40-30% rc (1)	.24	.30
9	C(silage), W wc seeding, no-till pl in c-k W (1)	.20	.24
10	C(RdL)-W(RdL, spring TP) (2)	.20	.28
11	C, fall shred stalks, chisel pl, 40-30% rc (1)	.19	.26
12	C-C-C-W-M, RdL, TP for C, disk for W (5)	.17	.23
13	C, RdL, strip till row zones, 55-40% rc (1)	.16	.24
14	C-C-C-W-M-M, RdL, TP for C, disk for W (6)	.14	.20
15	C-C-W-M, RdL, TP for C, disk for W (4)	.12	.17
16	C, fall shred, no-till pl, 70-50% rc (1)	.11	.18
17	C-C-W-M-M, RdL, TP for C, disk for W (5)	.087	.14
18	C-C-C-W-M, RdL, no-till pl 2d & 3rd C (5)	.076	.13
19	C-C-W-M, RdL, no-till pl 2d C (4)	.068	.11
20	C, no-till pl in c-k wheat, 90-70% rc (1)	.062	.14
21	C-C-C-W-M-M, no-till pl 2d & 3rd C (6)	.061	.11
22	C-W-M, RdL, TP for C, disk for W (3)	.055	.095
23	C-C-W-M-M, RdL, no-till pl 2d C (5)	.051	.094
24	C-W-M-M, RdL, TP for C, disk for W (4)	.039	.074
25	C-W-M-M-M, RdL, TP for C, disk for W (5)	.032	.061
26	C, no-till pl in c-k sod, 95-80% rc (1)	.017	.053
	COTTON[4]		
27	Cot, conv (Western Plains) (1)	0.42	0.49
28	Cot, conv (South) (1)	.34	.40
	MEADOW		
29	Grass & Legume mix	0.004	0.01
30	Alfalfa, lespedeza or Sericea	.020	
31	Sweet clover	.025	
	SORGHUM, GRAIN (Western Plains)[4]		
32	RdL, spring TP, conv (1)	0.43	0.53
33	No-till pl in shredded 70-50% rc	.11	.18

TABLE III-2 (Continued)

GENERALIZED VALUES OF THE COVER AND MANAGEMENT FACTOR, C, IN THE 37 STATES EAST OF THE ROCKY MOUNTAINS[1]- continued

Line no.	Crop, rotation, and management[3]	Productivity level[2]	
		High	Mod.
		C value	
SOYBEANS[4]			
34	B, RdL, spring TP, conv (1)	0.48	0.54
35	C-B, TP annually, conv (2)	.43	.51
36	B, no-till pl	.22	.28
37	C-B, no-till pl, fall shred C stalks (2)	.18	.22
WHEAT			
38	W-F, fall TP after W (2)	0.38	
39	W-F, stubble mulch, 500 lbs rc (2)	.32	
40	W-F, stubble mulch, 1000 lbs rc (2)	.21	
41	Spring W, RdL, Sept TP, conv (N & S Dak) (1)	.23	
42	Winter W, RdL, Aug TP, conv (Kans) (1)	.19	
43	Spring W, stubble mulch, 750 lbs rc (1)	.15	
44	Spring W, stubble mulch, 1250 lbs rc (1)	.12	
45	Winter W, stubble mulch, 750 lbs rc (1)	.11	
46	Winter W, stubble mulch, 1250 lbs rc (1)	.10	
47	W-M, conv (2)	.054	
48	W-M-M, conv (3)	.026	
49	W-M-M-M, conv (4)	.021	

[1] This table is for illustrative purposes only and is not a complete list of cropping systems or potential practices. Values of C differ with rainfall pattern and planting dates. These generalized values show approximately the relative erosion-reducing effectiveness of various crop systems, but locationally derived C values should be used for conservation planning at the field level. Tables of local values are available from the Soil Conservation Service.

[2] High level is exemplified by long-term yield averages greater than 75 bu. corn or 3 tons grass-and-legume hay; or cotton management that regularly provides good stands and growth.

[3] Numbers in parentheses indicate number of years in the rotation cycle. No. (1) designates a continuous one-crop system.

[4] Grain sorghum, soybeans, or cotton may be substituted for corn in lines 12, 14, 15, 17-19, 21-25 to estimate C values for sod-based rotations.

Abbreviations defined:

B - soybeans
C - corn
c-k - chemically killed
conv - conventional
cot - cotton
F - fallow
M - grass & legume hay
pl - plant
W - wheat
wc - winter cover

lbs rc - pounds of crop residue per acre remaining on *surface* after new crop seeding
% rc - percentage of soil surface covered by residue mulch after new crop seeding
70-50% rc - 70% cover for C values in first column; 50% for second column
RdR - residues (corn stover, straw, etc.) removed or burned
RdL - all residues left on field (on surface or incorporated)
TP - turn plowed (upper 5 or more inches of soil inverted, covering residues)

Source: U.S. EPA, 1975

TABLE III-3

"C" VALUES FOR PERMANENT PASTURE, RANGELAND, AND IDLE LAND (WISCHMEIER, 1972)[a/]

Vegetal Canopy Type and Height of Raised Canopy[b/]	Canopy Cover[c/] (%)	Type[d/]	Cover that Contacts the Surface — Percent Ground Cover					
			0	20	40	60	80	95-100
Column No.	2	3	4	5	6	7	8	9
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	0.45	0.24	0.15	0.090	0.043	0.011
Canopy of tall weeds	25	G	0.36	0.17	0.09	0.038	0.012	0.003
or short brush		W	0.36	0.20	0.13	0.082	0.041	0.011
(0.5 m fall height)	50	G	0.26	0.13	0.07	0.035	0.012	0.003
		W	0.26	0.16	0.11	0.075	0.039	0.011
	75	G	0.17	0.10	0.06	0.031	0.011	0.003
		W	0.17	0.12	0.09	0.067	0.038	0.011
Appreciable brush	25	G	0.40	0.18	0.09	0.040	0.013	0.003
or brushes		W	0.40	0.22	0.14	0.085	0.042	0.011
(2 m fall height)	50	G	0.34	0.16	0.085	0.038	0.012	0.003
		W	0.34	0.19	0.13	0.081	0.041	0.011
	75	G	0.28	0.14	0.08	0.036	0.012	0.003
		W	0.28	0.17	0.12	0.077	0.040	0.011

(continued)

TABLE III-3 (Continued)

Vegetal Canopy Type and Height of Raised Canopy[b]	Canopy Cover[c] (%)	Type[d]	Cover that Contacts the Surface, Percent Ground Cover: 0	20	40	60	80	95-100
Column No.	2	3	4	5	6	7	8	9
Trees but no appreciable low brush (4 m fall height)	25	G	0.42	0.19	0.10	0.041	0.013	0.003
		W	0.42	0.23	0.14	0.087	0.042	0.011
	50	G	0.39	0.18	0.09	0.040	0.013	0.003
		W	0.39	0.21	0.14	0.085	0.042	0.011
	75	G	0.36	0.17	0.09	0.039	0.012	0.003
		W	0.36	0.20	0.13	0.083	0.041	0.011

a/ All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists.

b/ Average fall height of waterdrops from canopy to soil surface: m = meters.

c/ Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

d/ G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 5 cm (2 in.) deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds) with little lateral-root network near the surface and/or undecayed residue.

TABLE III-4

"C" VALUES FOR WOODLAND (WISCHMEIER, 1972)

Stand Condition	Tree Canopy Percent of Area[a/]	Forest Litter Percent of Area[b/]	Undergrowth[c/]	"C" Factor
Well stocked	100-75	100-90	Managed[d/]	0.001
			Unmanaged[d/]	0.003-0.011
Medium stocked	70-40	85-75	Managed	0.002-0.004
			Unmanaged	0.01-0.04
Poorly stocked	35-20	70-40	Managed	0.003-0.009
			Unmanaged	0.02-0.09[e/]

a/ When tree canopy is less than 20%, the area will be considered as grassland or cropland for estimating soil loss.

b/ Forest litter is assumed to be at least 2-in. deep over the percent ground surface area covered.

c/ Undergrowth is defined as shrubs, weeds, grasses, vines, etc., on the surface area not protected by forest litter. Usually found under canopy openings.

d/ Managed - grazing and fires are controlled.
Unmanaged - stands that are overgrazed or subjected to repeated burning.

e/ For unmanaged woodland with litter cover of less than 75%, C values should be derived by taking 0.7 of the appropriate values in Table III-3. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland.

TABLE III-5

"C" VALUES FOR CONSTRUCTION SITES
(WATER RESOURCES ADMINISTRATION, 1973)

Type of Cover	C Value
None (fallow)	1.00
Temporary seedings	
First 60 days	0.40
After 60 days	0.05
Permanent seedings	
First 60 days	0.40
After 60 days	0.05
After 1 year	0.01
Sod (laid immediately)	0.01

Rate of Application

Mulch	In Metric Tons Per Hectare	In Tons Per Acre	C Value	Maximum Allowable Slope Length (ft)	Maximum Allowable Slope Length (m)
Hay or straw	1/2	1/2	0.34	20	6
	1	1	0.20	30	9
	1-1/2	1-1/2	0.10	40	12
	2	2	0.05	50	15
Stone or gravel	14	15	0.80	15	5
	55	60	0.20	80	24
	120	135	0.10	175	53
	220	240	0.05	200	61
Chemical mulches					
First 90 days		a/	0.50	50	15
After 90 days		a/	1.00	50	15
Woodchips	2	2	0.80	25	8
	4	4	0.30	50	15
	6	7	0.20	75	23
	11	12	0.10	100	30
	18	20	0.06	150	46
	23	25	0.05	200	61

a/ As recommended by manufacturer.

For croplands, control practices refer to contour tillage, cross-slope farming, and contour strip-cropping. The practice value P is the ratio of soil loss from a specified conservation practice to the soil loss occurring with up-and-downhill tillage, when other conditions remain constant. Table III-6 (USEPA, 1975) shows P values currently in common usage.

3.2.1.2.6 Sediment Delivery Ratio (S_d)

The sediment-delivery ratio, in this report, is defined as the fraction of the gross erosion which is delivered to some point in the stream system downstream of the source area. The classical method for determining an average delivery ratio is by comparing the magnitude of the sediment yield at a given point in a watershed (generally at a reservoir or a stream sediment measuring station), and the total amount of erosion. The quantities of gross erosion from sloping uplands are computed by erosion prediction equations for surface erosion, and estimated by various procedures for gullies, stream channels, and other sources. The sediment yield at a given downstream point is obtained through direct measurements. Estimates of the delivery ratio for some specific watersheds, particularly in the humid sections of the country, can be obtained from the Soil Conservation Service, USDA.

Many delivery-ratio studies have been aimed at finding measurable influencing factors that can be related to sediment-delivery ratio. A popular means of developing such information is by statistical analysis using the sediment-delivery ratio as the dependent variable and measurable watershed factors as the independent, or controlling variables. Many physical and hydrologic factors may influence sediment-delivery ratios. Empirical relationships for delivery ratios have been proposed and some are presented below. Estimates of sediment loading can be made through the use of these relationships, but such estimates should be tempered with judgment and consideration of other influencing factors not included in the quantitative expressions. The user is encouraged to consult with local experts and should use local data when available.

TABLE III-6

PRACTICE FACTORS (P) USED IN SEDIMENT LOADING EQUATION

Practice	Land slope (percent)				
	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
	(Factor P)				
Contouring (P_c)	0.60	0.50	0.60	0.80	0.90
Contour strip cropping (P_{sc})					
R-R-M-M[1]	0.30	0.25	0.30	0.40	0.45
R-W-M-M	0.30	0.25	0.30	0.40	0.45
R-R-W-M	0.45	0.38	0.45	0.60	0.68
R-W	0.52	0.44	0.52	0.70	0.90
R-O	0.60	0.50	0.60	0.80	0.90
Contour listing or ridge planting (P_{cl})	0.30	0.25	0.30	0.40	0.45
Contour terracing (P_t)[2]	[3] $0.6/\sqrt{n}$	$0.5/\sqrt{n}$	$0.6/\sqrt{n}$	$0.8/\sqrt{n}$	$0.9/\sqrt{n}$
No support practice	1.0	1.0	1.0	1.0	1.0

[1] R = rowcrop, W = fall-seeded grain, O = spring-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that rowcrop strips are always separated by a meadow or winter-grain strip.

[2] These P_t values estimate the amount of soil eroded to the terrace channels and are used for conservation planning. For prediction of off-field sediment, the P_t values are multiplied by 0.2.

[3] n = number of approximately equal-length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

Source: U.S. EPA, 1975.

The MITRE Corporation (1974) reported that the sediment delivery ratio for construction sites can be approximated by a function of the overland distance between the construction site and the receiving water:

$$S_d = D^{-0.22} \qquad \text{(III-2)}$$

where

D = overland distance between the erosion site and the receiving water, (ft).

The above equation was empirically derived from available data. The data base for the derivations includes values of D from 0 to 800 ft. MITRE suggests that this function should be further tested, particularly in areas of the Midwest and Central U.S.

For mining sites, logging roads and fire lanes, sediment delivery ratio relationships have not yet been established due to lack of systematically measured data. It is suggested that the delivery ratio developed by MITRE and expressed in Equation III-2 be used as the first approximation for these sites. This should be verified when appropriate data become available.

Sediment delivery ratios have been evaluated in many areas of the country, particularly the eastern half of the United States. The delivery ratio usually depicts a general trend in basins that are relatively homogeneous with respect to soils, land cover, climate, and topography. The Soil Conservation Service (1973) analyzed data from stream and reservoir sediment surveys from widely scattered areas.

This analysis shows that sediment delivery ratios vary inversely with "drainage basin size". It also indicates the effect of soil texture of upland soil on the sediment delivery ratio.

The delivery ratio relationships reported by SCS (1973) were used by an MRI study group in developing delivery ratios for sediment loading to watercourses. The result is shown in Figure III-9. The horizontal scale of the figure is the reciprocal of drainage density which is defined as the

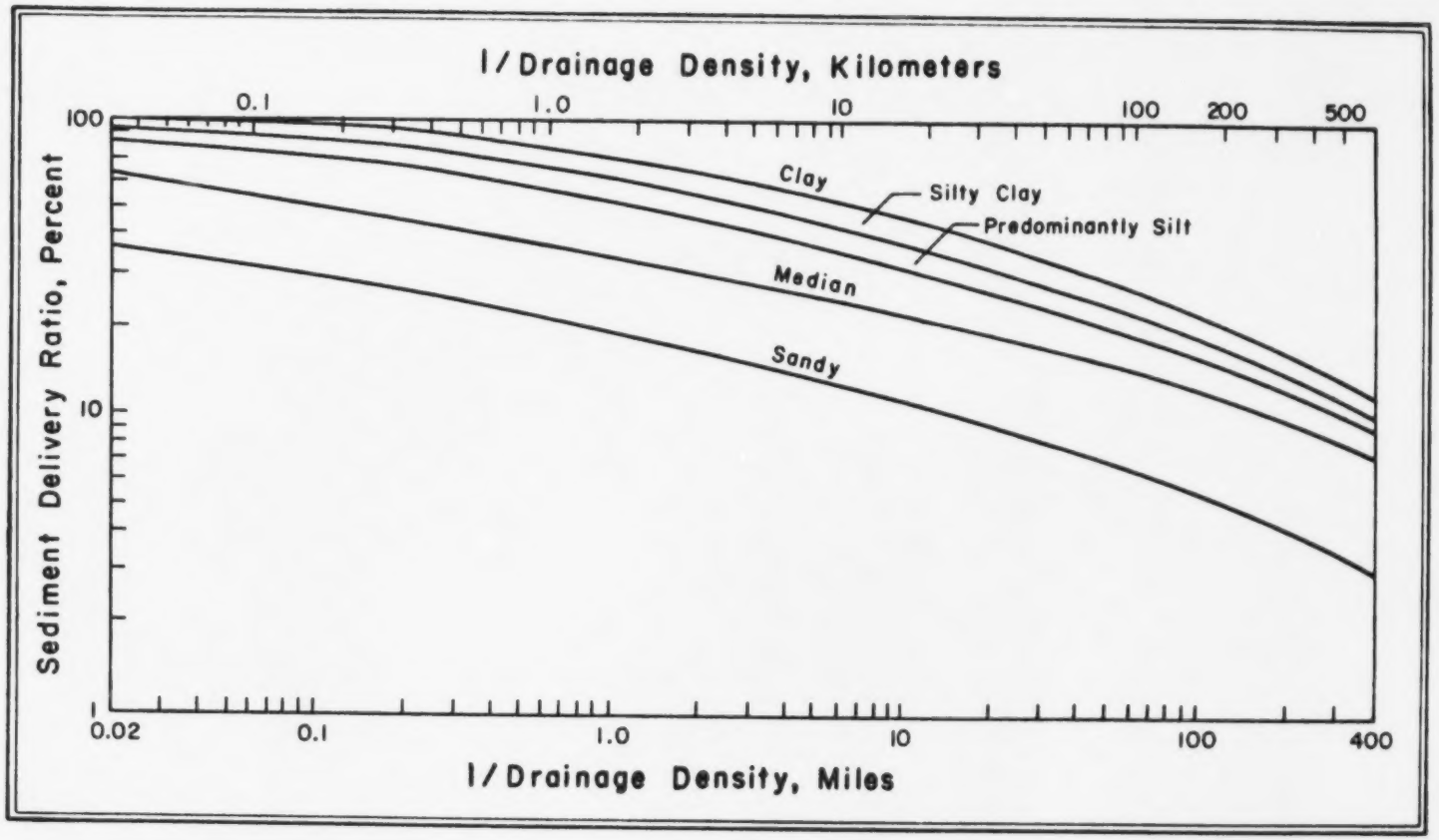

FIGURE III-9 SEDIMENT DELIVERY RATIO FOR RELATIVELY HOMOGENEOUS BASINS (MCELROY, ET AL., 1976)

ratio of total channel-segment lengths (accumulated for all orders within a basin) to the basin area. The reciprocal of drainage density may be thought of as an expression of the closeness of spacing of channels, or the average distance for soil particles to travel from the erosion site to the receiving water. The drainage density is found by dividing the total length of perennial streams in the waters and by the area of the watershed.

The delivery ratio relationship shown in Figure III-9 also takes into account the effect of soil texture. For example, if soil texture of upland soil is essentially silt or clay, the sediment delivery ratio will be higher than when the soil texture is coarse.

The following steps are to be used to obtain the delivery ratio (S_d) from Figure III-9.

1. Enter the figure on the horizontal axis with the value of the reciprocal of drainage density (1/DD).

2. Move vertically from the value of 1/DD to where it intersects the curve for the appropriate soil texture.

3. Read across from the point of intersection to the vertical axis. That number represents the delivery ratio, S_d.

A great range of values of drainage density exists in the United States, from 2 km/km^2 (3 miles/mile^2) for the Appalachian Plateau Province (Smith, 1950) to 500 km/km^2 (800 miles/mile^2) in Badlands at Perth Amboy, New Jersey (Schumm, 1956). In general, according to Strahler (1964), low drainage density is found in regions of highly resistant or highly permeable subsoil materials, under dense vegetative cover, and where relief is low. High drainage density is favored in regions of weak or impermeable materials, sparse vegetation, and mountainous relief.

Some typical values of drainage density for various locales in the U.S. are given in Table III-7. Local drainage density figures may be obtained from agencies such as the U.S. Geological Survey and the Army Corps of Engineers.

TABLE III-7

TYPICAL VALUES OF DRAINAGE DENSITY

Location	Drainage density km/km^2	Drainage density mile/mile^2	Reference
Appalachian Plateau Province	1.9-2.5	3.0-4.0	Smith (1950)
Central and eastern United States	5-10	8.0-16.0	Strahler (1952)
Dry Areas of the Rocky Mountain Region	31-62	50-100	Melton (1957)
The Rocky Mountain Region (except the above)	5-10	8.0-16	Melton (1957)
Coastal ranges of Southern California	12-25	20-40	Smith (1950) Melton (1957) Maxwell (1960)
Badlands in South Dakota	125-250	200-400	Smith (1958)
Badlands in New Jersey	183-510	310-820	Schumn (1956)

Measurements of drainage density can be made from a topographic map with a planimeter and chartometer. Care must be taken to include all permanent stream channels to their upper ends by checking in the field or with aerial photographs to verify topographic maps. A rapid approximation method for determining drainage density is suggested by Carlston and Langbein (1960).

3.2.1.3 Limitations and Accuracy of Sediment Loading Equation

The USLE predicts soil losses from sheet and rill erosion. It does not predict sediment from gullies, streambank erosion, landslides, road ditches, irrigation, or from wind erosion. The USLE was developed primarily for croplands, and has been chiefly based upon experimental plot data from the areas east of the Rocky Mountains. The loading function therefore is best defined for these areas of use. For croplands in the western United States and sources outside agriculture such as silviculture, construction, and mining, the factors have not been systematically developed, which seriously affects the ease of using the USLE for such sources.

The USLE was developed primarily as a means of predicting annual erosion losses. Although several methods have been proposed for using it to calculate losses from individual events the MUSLE (Williams, 1975) presented later in this chapter is recommended.

The loading function (Equation III-1) and supporting data in tables and figures were designed to predict longterm average loadings for specific conditions. Sediment loading for a specific year may be substantially greater or smaller than the annual averages because of differences in number, size, and timing of erosive rainstorms, and in other weather parameters. Table II of USDA Agriculture Handbook 282 (1965) contains a listing of 50, 20, and 5 percent probability values of R factor at 181 key locations in the area east of the Rocky Mountains. These may be used for further characterization of soil-loss hazards.

Because of year to year variations in climate and management factors, the average soil loss predicted by the USLE may be different from that occurring in any given year. Onstad et al. (1979) evaluated the precision of the USLE factors. The results (Table III-8) show that C is the most variable parameter followed by K, R, L and S. When the coefficients of variation for each parameter where used in an error propagation exercise, it was found that the coefficient of variation of soil loss prediction was roughly 107 percent.

EXAMPLE III-1

Assessing Sediment Loading from Surface Erosion

The watershed of interest has an area of 830 acres. It is located in Parke County, Indiana. Compute sediment loading from the watershed from sheet and rill erosion in terms of average annual loading.

Basic Information

Land use types:

- Cropland
- Pasture
- Woodland

Delivery ratio: 60 percent

Land information: (Cropland - 180 acres)

- Continuous corn on contours
- Conventional tillage, average yield, 40 to 45 bu
- Cornstalks are removed after harvest, winter crop seeded
- Spring turn plowed
- Soil - Fayette silt loam
- Slope - 6 percent
- Slope length - 250 ft

TABLE III-8

EROSION EQUATION FACTOR PRECISION ERROR

Factor	Number of		Range of means	Coefficient of Variation
	Reps	Treatments		
				%
Rainfall factor (R)	22 yr	42 loc.	57-231	34
Soil erodibility (K)	4 to 20 loc.	14 soils	0.11-0.41	39
Cropping management factor (C)	4 to 20 single plots	5 rotations	0.01-1.40	92
Slope steepness (s)	3	29	1.0-46.3	4
Slope steepness factor (S)			0.02-16.1	5
Slope length (l)	3	6	50-148	38
Slope length factor (L)			1.5-1.6	19

Source: Onstad, et al., 1979

Pasture: (220 acres)

- No appreciable canopy
- Cover at surface - grass and grasslike plants
- Percent of surface or ground cover - 80 percent
- Soil - Fayette silt loam
- Slope - 6 percent
- Slope length - 200 ft

Woodland: (430 acres)

- Medium stocked
- Percent of area covered by tree canopy - 50 percent
- Percent of area covered by litter - 80 percent
- Undergrowth - managed
- Soil - Bates silt loam
- Slope - 12 percent
- Slope length - 150 ft

Solution:

Cropland:

R = 200 (Figure III-2)
K = 0.37 (USDA-SCS)
LS = 1.08 (Figure III-8)
C = 0.49 (Table III-2)
P = 0.50 (Table III-6)
S = 0.60

Calculate average annual loading per acre.

$$Y(S)_{annual} = 200 \times 0.37 \times 1.08 \times 0.49 \times 0.50 \times 0.6$$
$$= 11.7 \text{ tons/acre-year}$$

Pasture:

R = 200
K = 0.37
LS = 0.95
C = 0.013 (Table III-3)
P = 1.0

S = 0.60

$$Y(S)_{annual} = 200 \times 0.37 \times 0.95 \times 0.013 \times 1.0 \times 0.6$$
$$= 0.548 \text{ tons/acre-year} = 1{,}100 \text{ lb/acre-year}$$

Woodland:

R = 200
K = 0.32
LS = 2.75
C = 0.003 (Table III-4)
P = 1.0
S = 0.60

$$Y(S)_{annual} = 200 \times 0.32 \times 2.75 \times 0.003 \times 1.0 \times 0.60$$
$$= 0.3168 \text{ tons/acre-year}$$

Calculations of Gross Loading

Average annual:

Cropland - 180 acres x 11.7 tons/acre-year	=	2114 tons/year
Pasture - 220 acres x 0.55 tons /acre-year	=	121 tons/year
Woodland - 430 acres x 0.32 tons/acre-year	=	138 tons/year
Total $Y(S)_E$	=	2374 tons/year

END OF EXAMPLE III-1

3.2.2 Single Event Sediment Loads

Soil erosion is governed by two processes: detachment of soil fines and transport of soil fines to the receiving water body. Detachment of soil fines can be accomplished by erosive rainfall or by shear forces at the soil surface created by surface runoff. One of the shortcomings of the USLE is that it does not explicitly consider transport nor detachment by runoff. Williams (1975) modified the USLE by replacing the "R" factor with a "runoff

energy" factor to provide more accurate sediment loss prediction for single storm events. In addition this modification eliminates the need for the sediment delivery ratio. The form of this modification is

$$Y(S)_E = 95\ (Vq_p)^{0.56}\ KLSCP \qquad \text{(III-3)}$$

where

$Y(S)_E$ = sediment yield in tons per event
V = volume of runoff in acre-feet and
q_p = peak flow rate in cubic feet per second

Other terms are as previously defined.

Alternatively the modified USLE (MUSLE) can be expressed in metric units as

$$Y(S)_E = 11.8\ (Vq_p)^{0.56}\ KLSCP \qquad \text{(III-4)}$$

where

$Y(S)_E$ = sediment yield in tonnes
V = volume of runoff (m^3)and
q_p = peak runoff rate (m^3/sec)

In order to use MUSLE the terms V and q_p must be evaluated. This is most conveniently accomplished using the Soil Conservation Service runoff curve number method (Mockus, 1972).

3.2.2.1 Evaluation of Total Storm Runoff

The depth of runoff from the watershed area is estimated by the following Equation:

$$Q = (R-0.2S)^2/(R+0.8S) \qquad \text{(III-5)}$$

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Appendix B

METHODS FOR PREDICTING SOIL ERODIBILITY INDEX "K"

APPENDIX B

METHODS FOR PREDICTING SOIL ERODIBILITY INDEX K

Nomograph for Predicting K Values of Surface Soils Using Chemical and Physical Parameters.

Nomograph for Predicting K Values of High Clay Subsoils Using Chemical Mineralogical and Physical Parameters.

NOMOGRAPH FOR PREDICTING K VALUES OF SURFACE SOIL

In 1971 Wischmeier, et al. (1971) presented a soil erodibility nomograph derived from statistical analysis of 55 soil types. Five soil parameters are included in the nomograph to predict erodibility: percent silt plus very fine sand; percent sand greater than 0.10 millimeter; organic matter content; soil structure; and permeability. Values of the parameters may be obtained from routine laboratory determinations and standard soil profile descriptions.

The nomograph is reproduced here as Figure B-1.

Description of Factors (Water Resources Administration, 1973)

Grain Size Distribution

Grain size distribution has a major influence on a soil's erodibility: the greater the silt content, the greater the soil's erodibility; the smaller the sand content, the greater the soil's erodibility.

Particles in the very fine sand classification behave more like silt than sand. Therefore, the percentage of very fine sand should be subtracted from the total percentage of sand and added to the percentage of silt.

Organic Matter

The percentage of organic matter was determined, in work by Wischmeier, et al., by the Walkley-Black method (Walkley and Black, 1934). The organic matter content is approximately 1.72 times the percent carbon. Soil erodibility decreases as organic matter content increases.

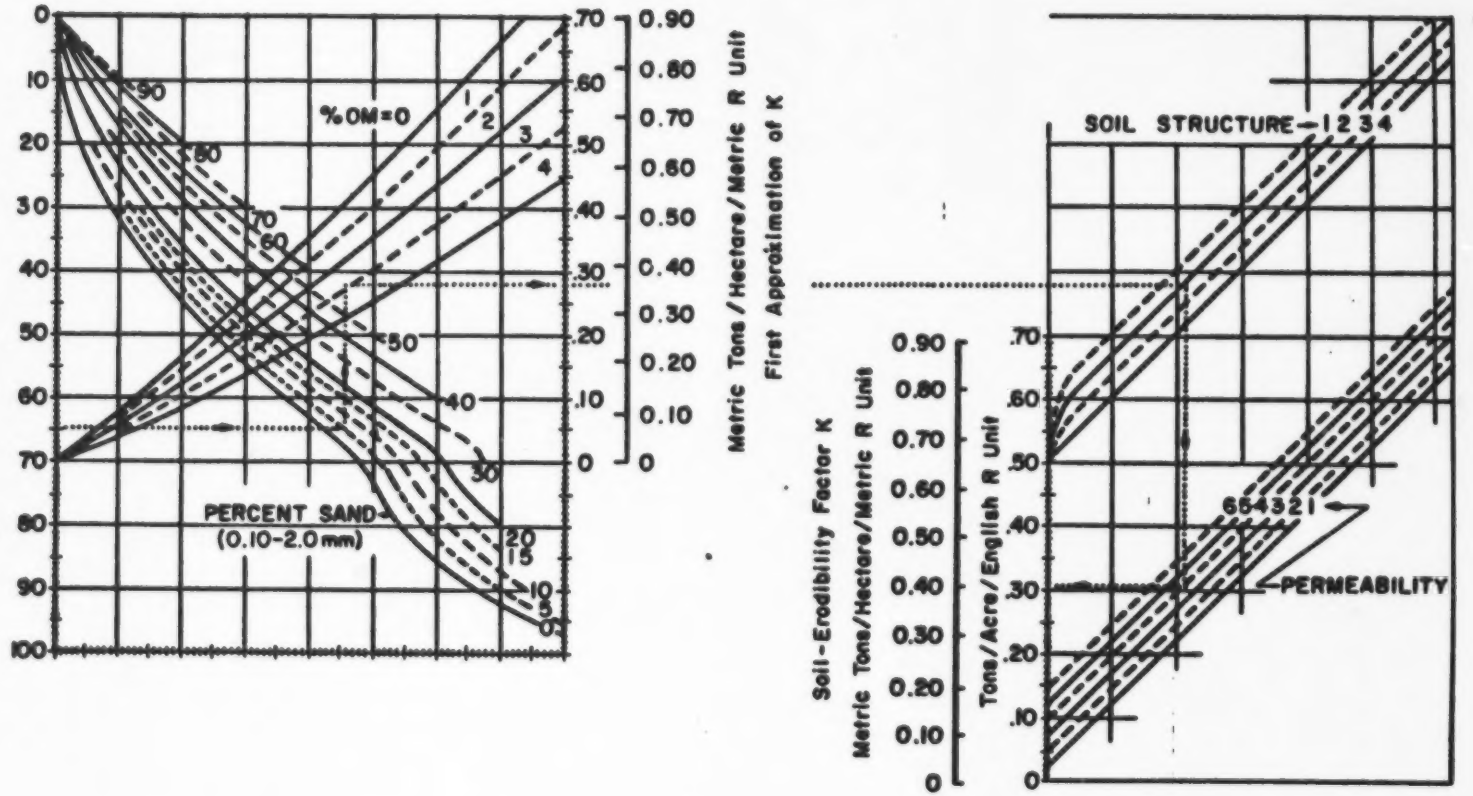

FIGURE B-1 SOIL ERODIBILITY NOMOGRAPH (WISCHMEIER ET AL., 1971)

Soil Structure

The soil structure is descriptive of the overall arrangement of the soil solids. The four parameter values and their descriptions are as follows:

Parameter Value	Descriptions
	Granular - All rounded aggregates may be placed in this category. These rounded complexes usually lie loosely and are readily shaken apart. When wetted, the voids are not closed readily by swelling.
1	Very fine granular - less than 1 mm.
2	Fine granular - 1 to 2 mm.
3	Medium granular - 2 to 5 mm.
3	Coarse granular - 5 to 10 mm.
4	Blocky - Aggregates have been reduced to blocks, irregularly six-faced, and with their three dimensions more or less equal. In size, the fragments range from a fraction of an inch to 3 or 4 in. in thickness.
4	Platy - Aggregates are arranged in relatively thin plates or lenses.
4	Prismatic - Aggregates or pillars are vertically oriented, with tops plane, level, and clean cut. They commonly occur in subsoils of arid and semi-arid regions.

Parameter Value	Descriptions
4	Columnar - Aggregates or pillars are vertically oriented, with rounded tops. They commonly occur when the soil profile is changing and the horizons are degrading.
4	Massive - Soil units are very large, irregular, featureless as far as characteristic aggregates are concerned.

Soil Permeability

Soil permeability is the ability of the soil to transmit water. Since different soil horizons vary in permeability, the relative permeability classes refer to the soil profile as a whole. The relative permeability classes are as follows:

Class	Permeability Rates in In/Hour	
1	Rapid	over 6.0
2	Moderately rapid	2.0 to 6.0
3	Moderate	0.6 to 2.0
4	Moderately slow	0.2 to 0.6
5	Slow	0.06 to 0.2
6	Very slow	less than 0.06

Reading the Nomograph

Entry values for all of the nomograph curves, except permeability class, are for the upper 6 or 7 in. of soil. For soils in cuts, the entry values are for the upper 6 or 7 in. of the newly exposed layer. In reading the nomograph, interpolate linearly between adjacent curves when the entry data do not coincide with the plotted curves of percent

sand or percent organic matter. The percent of coarse fragments may be significant and is not included in the nomograph. Therefore, reduce the value of K read from the nomograph by 10% for soils with stratified subsoils that include layers of small stones or gravel without a seriously impeding layer above them.

Enter the left scale of the nomograph with the appropriate percent silt plus very fine sand, move horizontally to intersect the correct percent-sand curve (interpolating to the nearest percent), vertically to the correct organic matter curve, and then horizontally to the right scale for first approximation of soil erodibility.

For soils having a fine granular structure and moderate permeability, the value of K can be obtained directly from this scale. However, if the soil is other than of fine granular structure, or permeability is other than moderate, it is necessary to proceed to the second part of the nomograph, horizontally to intersect the correct structure curve, vertically downward to the permeability curve, and horizontally to the soil erodibility index scale.

NOMOGRAPH FOR PREDICTING K VALUES OF HIGH CLAY SUBSOILS

Subsoils are commonly heavier in texture than the surface soils. In addition, subsoils likely have aggregating agents that are very much different from those found in surface soils and the degree of aggregation is known to have a profound influence on erodibility.

From an EPA study (Roth, et al., 1974) conducted at Purdue University, a multiple linear regression equation and nomograph were developed which can be used to estimate the erodibility factor, K, of many high clay soils. Multiple regression analysis revealed that

amorphous iron, aluminum and silicon hydrous oxides serve as soil stabilizers in subsoils (whereas, organic matter is the major stabilizer in surface soils). The nomograph was developed from the multiple linear regression equation relating the erodibility factor to the soil texture factor, M, the amount of CDB (citrate-dithionite-bicarbonate) extractable iron and aluminum oxides, and the amount of CDB extractable silica.

The equation used to derive the nomograph was:

$$K_{pred} = 0.32114 + 2.0167 \times 10^{-4} M - 0.14440 (\% Fe_2O_3 + \% Al_2O_3) - 0.83686 (\% SiO_2)$$

where

K_{pred} = predicted K value of subsoil

M = soil texture factor, defined by percent new silt (percent new silt + percent new sand). "New" silt has 2 to 100 μm mean diameter. "New" sand has 100 to 2,000 μm mean diameter.

$\% Fe_2O_3$ = percent CBD extractable iron oxide of soil.

$\% Al_2O_3$ = percent CDB extractable aluminum oxide of soil.

$\% SiO_2$ = percent CDB extractable silica in soil.

The nomograph for estimating the erodibility factor, K, of high clay subsoils is reproduced in Figure B-2.

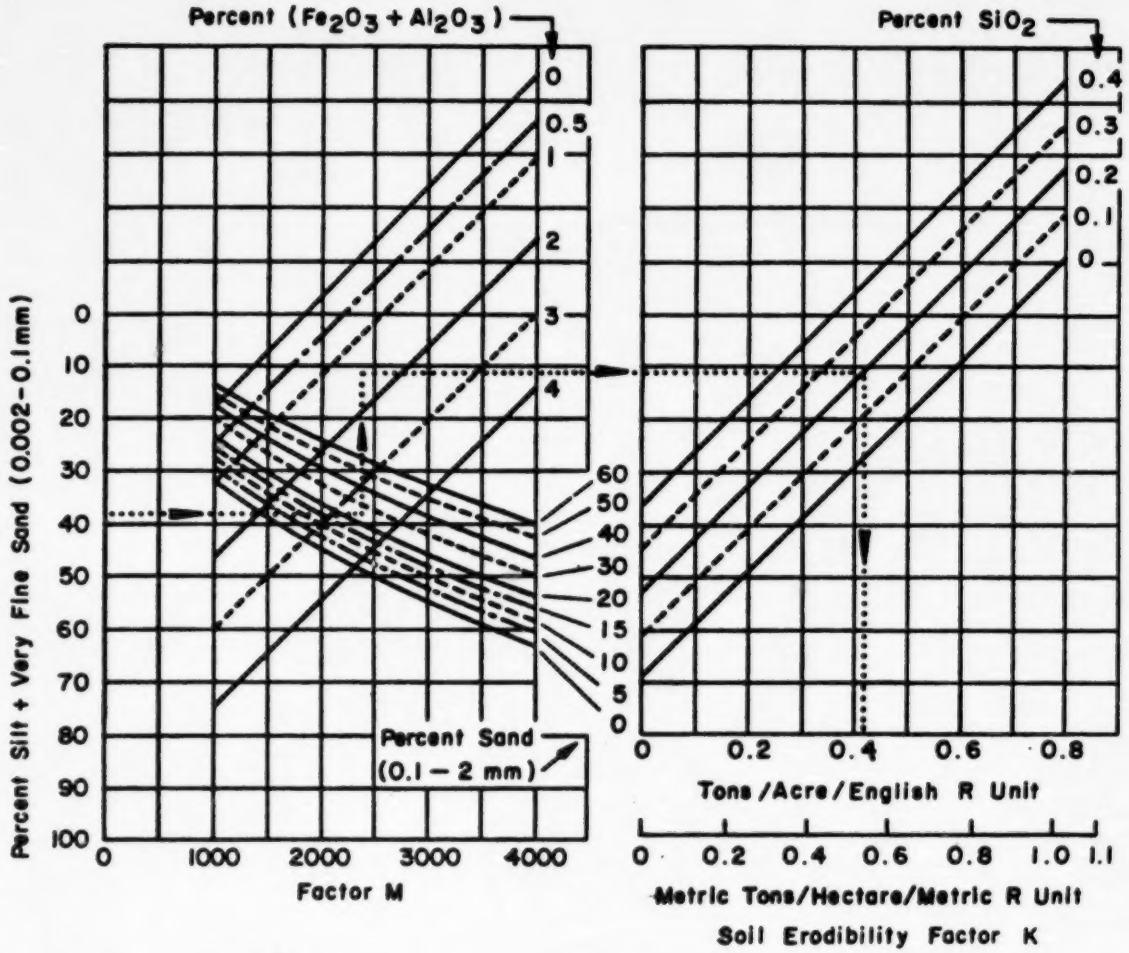

FIGURE B-2 NOMOGRAPH FOR ESTIMATING THE ERODIBILITY FACTOR K OF HIGH CLAY SUBSOILS (ROTH ET AL., 1974)

Appendix C

WASTE LOAD ALLOCATION MODEL
USER'S GUIDE
PENNSYLVANIA BUREAU OF WATER QUALITY MANAGEMENT

REFERENCES FOR APPENDIX B

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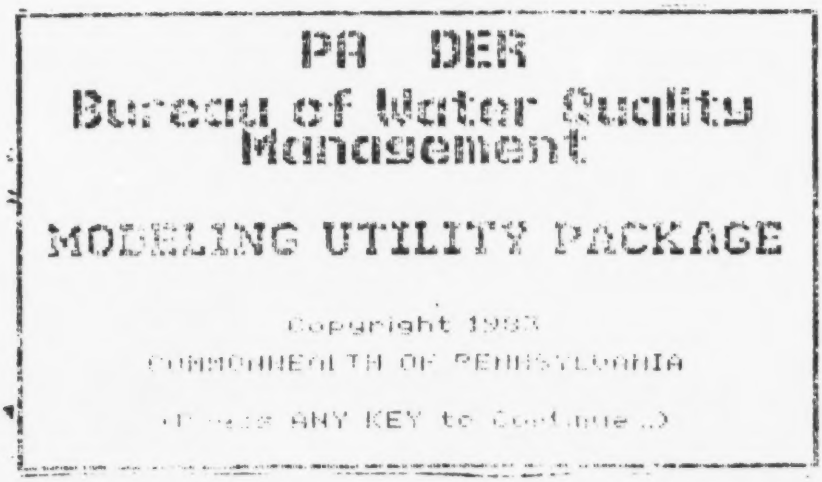
APPENDIX C

WASTE LOAD ALLOCATION MODEL
USER GUIDE



Pennsylvania Department of Environmental Resources
Bureau of Water Quality Management

May, 1983

PA DER BWQM MODELING SYSTEM

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DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF WATER QUALITY MANAGEMENT

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OVERVIEW

The DER Waste Load Allocation (WLA) Model is a package of computer programs designed to perform allocations, data management and reporting for two allocation procedures: equal effluent concentration and equal percent removal.

The programs operate on the APPLE II plus computers available in DER's Central and Regional offices.

This document describes the operation of this system, only. It does not discuss technical matters in great detail. This document is not intended to serve as a Policy and Procedure on wasteload allocations.

The WLA model is a two-stage Streeter-Phelps model that iterates over the segment, reducing effluent concentrations, until no DO or NH_3 violation is detected. The rules of this iteration process are included for your review and comment.

DER WASTE LOAD ALLOCATION MODEL

INTRODUCTION

The Waste Load Allocation (WLA) model is a stand-alone system of programs, that operate in an interactive mode, prompting the user at every point. There are two major operations - data management and data analysis.

Data management includes such operations as:

A. Entering new data
B. Saving new data on disk
C. Retrieving old data from disk
D. Displaying data on the monitor screen
E. Printing data
F. Updating data, and
G. Exchanging input data with output from the model.

Data analysis includes:

A. DO profile of projected conditions, and
B. Performing WLA runs in automatic or stepped mode.

The DO profile option will evaluate the input data using a two-stage Streeter-Phelps routine similar to the DER-DOSAG model also contained on the BWQM Master Disk.

The WLA option performs three steps:

1. Analysis of projected conditions and identification of DO and NH_3 (total and unionized) violations,

2. An equal effluent concentration allocation, and

3. An equal percent removal allocation.

As the model searches for effluent concentrations which meet water quality criteria, various instream concentrations are displayed to give the user a sense of the stream's response to decreases in waste loads.

Following the allocation runs, the program automatically enters the report routine which will display the WLA results and optionally allow for printing of the results.

After printing, the model returns the list of major options, the MENU, which would allow the user to perform any data management necessary before exiting the program.

The general operating sequence of the WLA model is as follows:

1. Test conditions defined in input for ammonia or DO violations.

2. If ammonia violations are noted, i.e., the less stringent of the total or unionized, begin reducing NH_3N concentrations until no violations are found.

3. If DO violations are noted in Step 1, above, begin reducing BOD concentrations until no violations are found.

4. If BOD concentrations are reduced too low, reduce NH_3N further than required for Step 2, and repeat Step 3.

Obviously, there are subtle tests and program paths needed to handle contingencies in the above four steps, but they are not addressed here.

OPERATING THE WLA MODEL

STARTING

These instructions assume that the user has only a minimum of experience on the Apple computer and is familiar with basic operation of the Apple keyboard and the disk drive.

If the Apple is turned OFF, place the diskette labeled "BWQM MASTER DISK" in disk drive #1 and turn on the Apple.

If the Apple is ON from another use, insert the same disk and type:

PR#6

This will cause the Apple to execute the HELLO program which displays the system banner shown in Figure I, below. The banner contains the Version number.

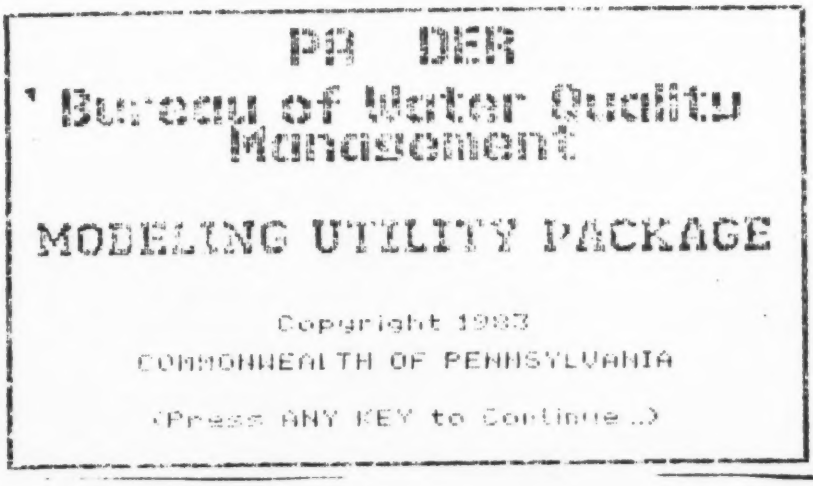

FIGURE 1 - SYSTEM BANNER

The system will pause at this point waiting for a key-stroke, upon which the MENU program will be run. The programs available on this disk will be listed, and the program contained on Version IV are shown in Figure 2, below:

```
PENNSYLVANIA DER MODELING UTILITY DISK

    1 - D.O. SAG PROFILE
    2 - WASTELOAD ALLOCATION (TEST)
    3 - REAERATION (KR) FORMULAE
    4 - CARBONACEOUS DECAY (KC)
    5 - DIVERSITY INDEX
    6 - STRESS RECOVERY INDEX
    7 - LEAST SQUARES REGRESSION
   99 - EXIT
ENTER PROGRAM NUMBER (1-7 OR 99) ?
```

FIGURE 2 - SYSTEM MENU

The wasteload allocation model is Program #5 on this disk. To execute this program, enter a "5" and press the "RETURN" key. This will initiate the WLA model which also begins with a banner showing the version and release date. The Version I banner is shown in Figure III, below:

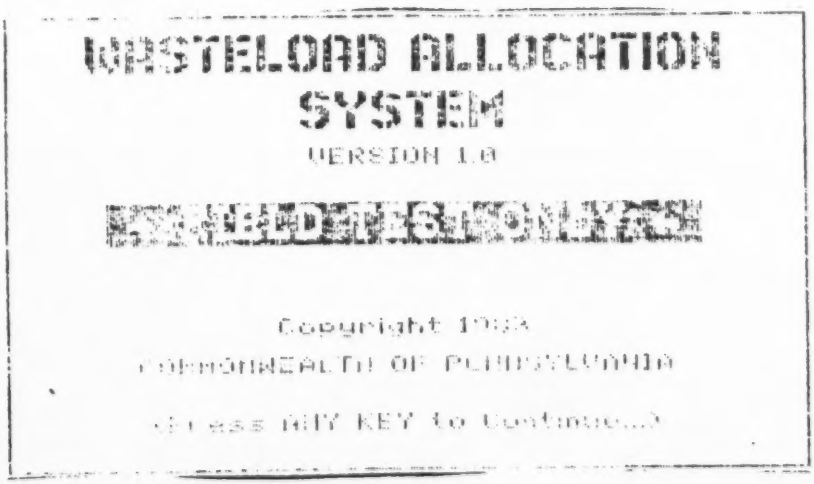

FIGURE 3 - WLA BANNER

NOTE: Version ONE is being released for "field testing". This means that you should be especially careful in choosing input and applying output. Not only should you watch for program errors, but also for application errors, i.e, misinterpretation of the results. Please report all suspected problems, including areas that need clarification.

Following this pause, the WLA MENU will be displayed, as shown in Figure 4.

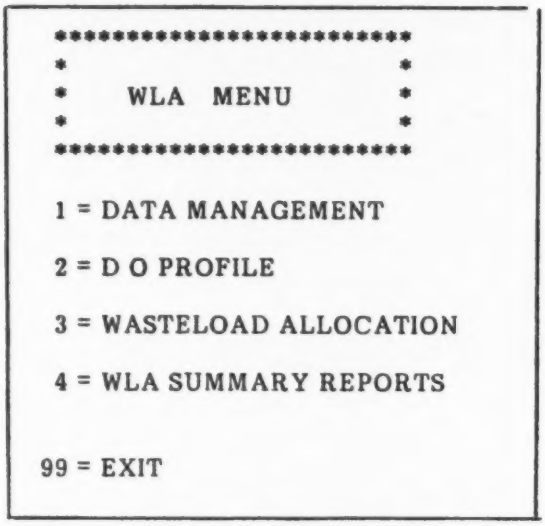

FIGURE 4 – WLA MENU

The five values printed above are the only acceptable responses to this prompt. Options 1 through 4 are discussed in the sections below. Option 99 will terminate the program provided the data currently in memory has been saved on disk. If not, the user will be reminded to save the data, and must respond with a "Y" or "N" before proceeding.

OPTION # 1 - DATA MANAGEMENT

Selection of Option #1, data management, in the WLA Menu (see Figure 4) will load and execute the program, WLA.DATA.MGT, which displays a list of seven basic options and an exit. (Option #9, "Return to Menu" will reload the menu program illustrated by Figure 4.)

The data management menu is shown in Figure 5, below:

```
W L A  DATA MANAGEMENT PROGRAM

 1 = INPUT      - NEW DATA
 2 = GET        - DATA FROM DISK
 3 = SAVE       - DATA TO DISK
 4 = UPDATE     - DATA IN CORE
 5 = DISPLAY    - DATA IN CORE
 6 = SWAP       - DATA IN CORE (CODE = 0)
 7 = PR#        - SLOT NUMBER (PR# = 1)

 9 = RETURN TO MENU

 ENTER OPTION NUMBER (1 - 7 or 9) 1
```

FIGURE 5-DATA MANAGEMENT MENU

DATA MANAGEMENT OPTIONS:

OPTION #1 - Input

The first time a water quality limited segment is analyzed, the data must be entered via the INPUT option. In this option, the user will be prompted individually for nine

headwater items and 13 items for each reach in the segment (five describing the reach and eight describing the discharger) as described below.

Headwater Data

The first series of prompts is shown in Figure 6 below:

```
                    D E R  -  WLA INPUT

                  VERSION 1.0...NOV. 1982
*****************************************

INITIAL (HEADWATER) CONDITIONS...

DESCRIPTION (25 CHARACTERS)...
?SWAMP CREEK
FLOW (Q-CFS)---150
DO   (MG/L)----9
BOD-5(MG/L)----4
NH3N (MG/L)----.3
PH -----------7
TEMP (CENT)----20
WARM OR COLD WATER (W OR C)...COLD

NUMBER OF REACHES (1-10) ?4
```

FIGURE 6 - INPUT PROMPTS (HEADWATER)

Note: In this Example and those which follow, all user input is underlined.

Description - This entry may consist of any combination of characters. This title will appear on all reports and should describe the data in some general way. This

will be saved with the data on disk and may serve to refresh the users memory at some later date.

Flow (Q-CFS) - Enter the low flow rate in cubic feet per second (i.e., design flow) upstream of the first discharger. This flow should not include the flow from the first discharger.

NOTE: When entering numeric data, it is not necessary to enter a decimal point unless it is needed.

DO, BOD-5, NH3N (MG/L) - Enter the concentrations of these three parameters in milligrams per liter upstream of the first discharger.

pH - Enter the instream pH above the first discharger. This parameter is used in calculating the concentration of unionized ammonia to check for violations.

TEMP (CENT) - Enter the instream temperature in Celsius. This is used for unionized ammonia calculations, K-rate adjustments, and saturation DO calculations.

WARM OR COLD - Enter either the letter "W" or "C" to identify the stream as being a warm water or cold water stream, as per Chapter 93. This determines the maximum allowable concentrations of unionized ammonia and ammonia nitrogen.

NOTE: At the present time, the setting of special values for the ammonia violation test is not permitted.

NUMBER OF REACHES (1-10)? - Enter a value (no decimal allowed) to set the number of reaches. A reach is defined as starting with:

A. A discharger,

B. A tributary, or

C. A change in K-rates.

The user must enter 13 values for each reach identified here. Keep in mind that no reaches may be added or deleted later, but dischargers can be removed from the allocation process or their flows can be set to zero.

Reach Data

```
GENERAL REACH DATA          REACH # 1
TIME  (DAYS)----2
DEOX-K1 (/D)----2
REAR-K2 (/D)----3
NITR-KN (/D)----1
TRIB=1, DC=0----0
```

FIGURE 7 - INPUT PROMPTS (REACH DATA)

The five prompts needed to define the reach are shown in Figure 7, above.

The TIME (DAYS) prompt refers to this reach, only.

The three K-rates (K1, K2, KN) must be entered in adjusted form i.e., adjusted to 20°C if necessary. They will be adjusted up or down from 20°C to the temperature resulting from the mixing of the stream and the discharger. The rates are in base "e" per day.

The final prompt in Figure 4 is referred to as the "Trib Switch". Entry of "1" in response to the prompt identifies this reach/discharger as a tributary and therefore cannot be part of the allocation process. The effluent concentrations will not be reduced to avoid a violation. This value, like all others, can be changed later if so desired.

Discharger Data

```
                DISCHARGER DATA
                    EFFLUENT        INFLUENT
FLOW   (MGD)-----1M
BOD-5  (MG/L)----45              ?1M0
NH3-N  (MG/L)----2.375           ?3M
PH---------------2
DO     (MG/L)----5
TEMP   (CENT)----20
```

FIGURE 8 - DISCHARGER DATA PROMPTS

The eight prompts above provide the data necessary to describe a discharger or a tributary. Any or all of these may be zero.

The flow (in MGD), BOD, NH3, PH, DO, and TEMP values describe the EFFLUENT and are used in the same ways as those described in the paragraph above for Headwater. The selection of flow and load data depends upon the allocation step being performed. For example, if a basic allocation of assimilative capacity is being performed, the input data should be the design conditions of the dischargers involved. If, however, five-year NPDES permit conditions are being considered for the segment, then all flows and loads, both influent and effluent, should be changed appropriately.

The EFFLUENT data is used for the equal effluent concentration allocation. The INFLUENT data for BOD-5 and NH3-N is used (along with the remaining effluent data) for the equal percent removal allocation.

The last two prompts described the INFLUENT to the plant. These values are used for WLA Method #2, The Equal Percent Removal Method.

OPTION #2 - Get

This option is used to retrieve data from disk. Following selection of this option, the user will be asked for a file name. The program will then attempt to locate the file on the disk and read the data into memory. Any data in memory at the time of the GET will be erased, i.e., overwritten.

OPTION #3 - Save

This option is used to copy data from memory to disk. The user must enter a file name, as in Option #2, above.

> NOTE: Entry of an existing file name will cause the data to overwrite the existing file, regardless of the user's intent.

OPTION #4 - Update

This option is used to change the data currently in memory. The data could have been entered via Option #1, Input, or Option #2, Get From Disk.

The data is changed in blocks. For example, if you wish to change a value in the headwater section, <u>all</u> existing headwater data will be displayed. If the current value is acceptable, press the (→) right arrow key to pass over the value on the screen and press RETURN. Repeat this process until reaching a value to be updated.

To change a value displayed, simply retype the data and press RETURN.

Following the last change needed, entry of a CONTROL-C, RETURN will return control to the Data Management Menu (Figure 5), and preserve the changes made.

If the user wishes to change data for a reach or a discharger, the reach number will also have to be entered when requested. The process for keeping data, changing data, or returning to the menu is the same as described in the paragraphs above.

> NOTE: After the correction has been made, you may return to the menu by entering a "RETURN" in response to the next item. A "RETURN" with no preceeding data will trigger a branch back to the menu.

OPTION #5 - Display

This option displays the data currently in memory, regardless of its source. If the data came from file, the file name will be shown in the header. Changes made through the update option are also shown.

The reaches are displayed in five-digit columns. If more than six reaches are involved, the program will pause between screens. Data may be truncated for display, but are <u>not</u> truncated in memory. If more than six reaches are used, pressing RETURN will continue the display.

```
                    WLA INPUT LISTING
                    FILE = WLA.DATA4

HEADWATER DATA

DESC:SWAMP CREEK
  FLOW (CFS)--150
  DO  (MG/L)--9
  BOD5--------3
  NH3-N-------.3
  PH----------7
  TEMP (CENT)-20
  WARM/COLD---COLD

                    REACH DATA

REACH #   1        2        3        4
TIME---.500000 1.00000 2.00000 .100000
KC-----2.00000 2.00000 2.00000 2.00000
KR-----3.00000 3.00000 3.00000 3.00000
KN-----1.00000 1.00000 1.00000 1.00000
TRIB---       0        0        1        0

EFFLUENT:
Q(STP)-10.0000 20.0000 10.0000 10.0000
BOD-5--45.0000 45.0000 50.0000 50.0000
NH3-N--2.37500 5.00000 3.00000 10.0000
PH-----7.00000 7.00000 7.00000 7.00000
DO-----5.00000 3.00000 2.00000 5.00000
TEMP---20.0000 20.0000 20.0000 20.0000

INFLUENT:
BOD-IN 100.000 100.000 150.000 200.000
NH3-IN 30.0000 40.0000 50.0000 30.0000
```

FIGURE 9 - DISPLAY OPTION

After the data has been displayed, a printout option appears. The printout will be directed to the slot (generally #1) that is shown in Option #7 of the data management menu. Following printing, control is returned to the menu.

OPTION #6 - Swap

This option can be used to replace the BOD and NH3 effluent concentrations currently in memory with the results of previous allocation runs.

This allows for the results to be swapped into memory (as input) for display and printing. This set of data can then be run through the DO profile option to get a detailed description of the results of an allocation.

OPTION #7 - PR#

Selection of this option allows the user to change the slot number of the printer, in case more than one has been installed. Selection of an invalid slot number, i.e., one without a printer, will cause the system to "hang". Control can be retained by using "RESET".

OPTION #2 - D. O. PROFILE

Option #2 will use the data in memory (whether from input, get, swap, or update options), and calculate a DO profile. Also calculated are NH_3N and BOD-5 concentrations.

This subroutine breaks each reach into 10 subreaches and calculates concentrations at eleven points per reach - upstream of subreach one to downstream of subreach ten. The concentrations at the upstream end of subreach one represent the "complete mix" concentrations at time zero for the reach.

The DO Profile subroutine is a two-stage Streeter-Phelps steady-state stream model. The specific modeling equation used contains terms for reaeration, deoxygenation, and nitrification. Thus, this model is equivalent to the "two stage model" available on the WANG calculator, DOSAG on the Burroughs, and DOSAG-II on the Apple.

All references to dissolved oxygen (DO) are in actual concentration, not as a deficit, at the actual temperature of the reach, after dilution. All K-rates are adjusted from 20 degrees Centigrade. Loads are input and output in 5-day values. Internal calculations, however, are performed as ultimate loads.

Note that both this model and the WANG model are called "two stage models." However, neither model contains a delay on the start of nitrification. The "actual" point of highest demand caused by nitrification is not only related to load and k-rate, but also to the structure of the stream. Shallow rocky streams cause nitrogenous oxygen demand to start at the outfall, while slow streams or ones with silty bottoms allow the demand to pass unmet downstream. In this model, these effects are ignored and all oxygen consuming materials exert their demand simultaneously and immediately.

In Version 4, this subroutine, like DOSAG on the Apple does not currently accept lateral inflow, e.g., non-point source loads or dilution. DOSAG on the Burroughs computer must be used when NPS flows or loads are critical.

Processing Sequence

When Option #2 is selected, the data in core will be evaluated as follows:

1. Headwater data is mixed with discharger data,

2. K-rates are adjusted from 20°C to the mix temperature,

3. BOD_5, NH_3-N and DO are calculated at each subreach, i.e., one-tenth of a reach,

4. At end of subreach ten, the results are moved into the headwater slot and processing loops back to step #1, above.

This processing can be followed by the user by the screen display of the reach and subreach numbers.

Following processing of the last subreach, a graphic display will appear giving a picture of the DO profile. This is shown in Figure 10, below. The horizontal axis subdivisions represent subreaches. The vertical axis has two markings representing 5 mg/l and 6 mg/l DO concentrations. This graph will remain on the screen until a key is pressed. By pressing the "X" key, the following tables will be skipped. By pressing the "P" key, the graph will be printed. (Note: If the first graph is printed in inverse, i.e., white on black, it will correct itself for the second graph.)

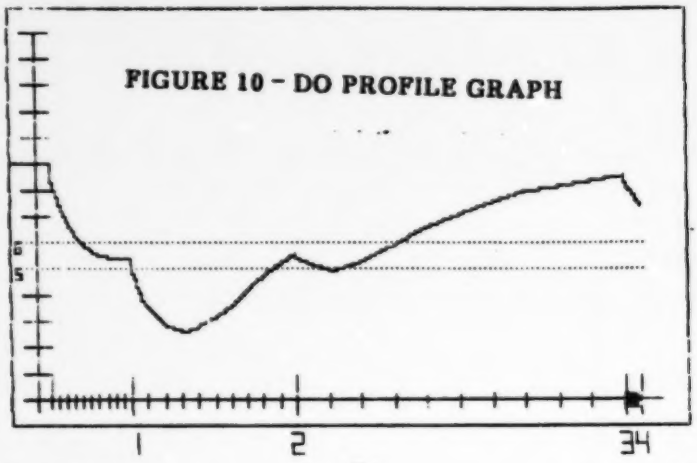

FIGURE 10 - DO PROFILE GRAPH

REACH 1 PROFILE
FILE = WLA.DATA4
SWAMP CREEK

SUBRCH	DO	BOD-5	NH3
0	8.63	6.93	.49
1	7.66	6.27	.47
2	6.92	5.67	.45
3	6.37	5.13	.43
4	5.97	4.64	.4
5	5.7	4.2	.38
6	5.53	3.8	.37
7	5.44	3.44	.35
8	5.41	3.11	.33
9	5.43	2.82	.32
10	5.49	2.55	.3

REACH 2 PROFILE
FILE = WLA.DATA4
SWAMP CREEK

SUBRCH	DO	BOD-5	NH3
0	5.1	9.24	1.04
1	3.57	7.56	.94
2	2.86	6.19	.85
3	2.69	5.07	.77
4	2.86	4.15	.7
5	3.22	3.4	.63
6	3.7	2.78	.57
7	4.21	2.28	.52
8	4.73	1.86	.47
9	5.23	1.53	.42
10	5.7	1.25	.38

REACH 3 PROFILE
FILE = WLA.DATA4
SWAMP CREEK

SUBRCH	DO	BOD-5	NH3
0	5.43	4.81	.57
1	4.94	3.22	.47
2	5.32	2.16	.38
3	5.96	1.45	.31
4	6.62	.97	.26
5	7.19	.65	.21
6	7.65	.44	.17
7	8	.29	.14
8	8.27	.2	.12
9	8.47	.13	.09
10	8.61	.09	.08

REACH 4 PROFILE
FILE = WLA.DATA4
SWAMP CREEK

SUBRCH	DO	BOD-5	NH3
0	8.36	3.48	.75
1	8.25	3.42	.75
2	8.14	3.35	.74
3	8.03	3.28	.73
4	7.93	3.22	.72
5	7.84	3.15	.72
6	7.75	3.09	.71
7	7.66	3.03	.7
8	7.58	2.97	.7
9	7.51	2.91	.69
10	7.44	2.85	.68

TABLE 1 - SAMPLE DO PROFILE REPORTS

Following the graph, a table will be displayed showing the BOD, DO and NH_3 concentrations for each subreach. A one-screen table will be displayed for each reach. The table will remain on the screen until either a "Return" is entered or the letter "P" is entered. See Table 1, above.

The "Return" will continue processing to the next screen, or MENU if complete. The "P" will direct a copy of the screen to the printer before moving to the next screen. An "X" will skip the reports and branch back to the menu.

Equations

The following equations are used in both the DOSAG routine and the WLA routines.

K-rates will be adjusted by the program from 20°C, using the following: $K_t = K_{20}\emptyset^{(T-20)}$

where: $\emptyset_C = 1.047$
$\emptyset_R = 1.024$
$\emptyset_N = 1.080$

Input data of 5-day loads will be converted to ultimate by multiplying carbonaceous by 1.50 and nitrogenous by 4.57.

To convert a DO value to a deficit for internal calculations, the program uses the equation listed below to calculate the saturation concentration at temperature T:

$$C_s = 14.652 - 0.41022T + 0.00799T^2 - 0.00007777T^3$$

The following equation is used for upstream dilution:

$$C_2 = \frac{(C_0 * Q_0) + (C_1 * Q_1)}{(Q_0 + Q_1)}$$

The Streeter-Phelps equation is used to compute downstream deficit (D_i):

$$Di = \frac{K_C L_0}{K_R - K_C}\left[e^{-K_C t} - e^{-K_R t}\right] + D_0\left[e^{-K_R t}\right] + \frac{K_N N_0}{K_R - K_N}\left[e^{-K_N t} - e^{-K_R t}\right]$$

The downstream loads are computed as:

$$Li = L_0 e^{-K_C t}$$
$$Ni = N_0 e^{-K_N t}$$

where:

C =	Concentration (mg/l)	K_R	= Reaeration rate (l/day)
Q =	Flow (cfs or MGD)	K_N	= Nitrification rate (l/day)
D =	Deficit (mg/l)	t	= Time (days)
L =	BOD-C (mg/l)	T	= Temperature (^oC)
N =	BOD-N (mg/l)		
K_C =	Deoxygenation rate (l/day)		

OPTION #3 - WASTELOAD ALLOCATIONS

This routine will perform three major functions using the data in memory.

1. Evaluate the design conditions data to locate violations in dissolved oxygen and/or ammonia toxicity.

If no violations of the Chapter 93 criteria are identified, processing returns to the MENU.

2. Perform an Equal Effluent Concentration allocation on each discharger identified by a "Ø" in the "Trib Switch":

   a. Reduce each discharger's NH_3-N loading until no ammonia violation, total or unionized, is predicted based on the temperature and pH of the mix.

      This is performed by first reducing (or raising) each DC's NH_3-N load to minimum treatment, e.g., 10 mg/l. Then each is reduced by an equal amount and the DC's are modeled. This is repeated until no violation is noted. If the effluent concentration is reduced below a pre-set minimum (1 mg/l), then the allocation run is abandoned and Method #2 is started. (See Step #3 below).

   b. Once the NH_3 is set, the same process is initiated on the BOD load. The loop is started at 30 mg/l and reduced by equal percentage steps until no violation is recorded by a DOSAG run. If the BOD is reduced below 1 mg/l, then the NH_3 load is reduced further, if possible, and step (b) is repeated.

   This process can be followed by the user by watching the monitor. The reach being modeled is printed along with the concentration. Once no violation is found, the effluent concentrations are displayed and processing continues.

3. Perform an Equal Percent Removal allocation on each discharger identified by a "Ø" on the "Trib Switch".

This method follows the procedure outlined in steps 2(a) and 2(b) above, except that the effluent is calculated by removing an increasing percentage of the influent.

Following method #2, the processing will proceed automatically to Option #4, the WLA Report routines.

The results of an allocation run, as shown on the screen, are given by Figure 11, below.

```
            WLA MODEL - MAIN SEQUENCE
-------------------------------------------

EXISTING CONDITIONS:
     AMMONIA: VIO IN RCH # :2,4,
     DIS OXY: VIO IN RCH # :1,2,
-------------------------------------------

METHOD #1 - EQUAL EFFLUENT CONCENTRATION
     AMMONIA: NO VIO @ EFF CONC = 2.25
     DIS OXY: NO VIO @ EFF CONC = 30
-------------------------------------------

METHOD #2 - EQUAL PERCENT REMOVAL
     AMMONIA: NO VIO @ PCT REM = 93
     DIS OXY: NO VIO @ PCT REM = 87
                DO=8.87895783


END OF ALLOCATION RUNS
PRESS ANY KEY TO CONTINUE...
```

FIGURE 11 - WLA RUN SCREEN

OPTION #4 - WLA REPORTS

The WLA reports will be generated automatically following the allocation runs (Option #3). This, however, is also a MENU option to allow for returning to the reports as a matter of convenience.

Currently, there are two reports, displayed one at a time, followed by an option to have the report copied to the printer. Samples of these reports are shown in Figure 12, below.

WLA SUMMARY REPORTS
FILE: WLA.DATA4
SWAMP CREEK

EFFLUENT CONCENTRATIONS

	EXISTING		METHOD#1		METHOD#2		PCT. REM.	
R#	BOD-5	NH3-N	BOD-5	NH3-N	BOD-5	NH3-N	BOD-5	NH3-N
1	45.0	2.37	8.47	2.37	2.00	6.00	98.0	80.0
2	45.0	5.00	8.47	5.00	2.00	8.00	98.0	80.0
3	50.0	3.00	50.0	3.00	50.0	3.00	.000	.000
4	50.0	10.0	8.47	10.0	4.00	6.00	98.0	80.0

WLA SUMMARY REPORTS
FILE: WLA.DATA4
SWAMP CREEK

MINIMUM WATER QUALITY

	EXISTING		METHOD#1		METHOD#2		CONC.UNIONIZED		
R#	D.O.	NH3-N	D.O.	NH3-N	D.O.	NH3-N	EXIST	MET#1	MET#2
1	5.40	.494	6.92	.494	6.90	.832	.001	.000	.003
2	2.69	1.04	6.02	1.04	6.05	1.68	.004	.000	.006
3	4.94	.573	6.17	.573	6.01	.794	.002	.000	.003
4	7.43	.752	8.13	.752	8.25	.508	.002	.000	.002

FIGURE 12 - SAMPLE WLA REPORTS

OPERATING COMMENTS

Segment Definition

The WLA Model assumes that all data sets entered represent members of one water quality limited segment. This implies that an interaction or interrelationship exists between dischargers. This however may not be the case, and some testing should be performed to answer the question.

To facilitate such testing, the "trib switch" was added to the input. Setting this switch to "1" removes the discharger from the allocation process. This effectively turns the discharger into a tributary. This represents an uncontrollable point source and a load that cannot be reduced. In addition to setting the trib switch, the effluent concentrations may be changed via the data management option.

The fundamental question which must be addressed is:

> Can the stream be restored to background (not necessarily headwater) conditions between dischargers by reducing combinations of dischargers, but not all?

To test this question, numerous changes to the data may be necessary. The typical usage pattern might be:

1. Input new data
2. Save data
3. Run DO profile
4. Run WLA
5. Review reports
6. Change data
7. Run WLA . . . . etc.

The first report displays the effluent concentrations. Columns 2 and 3 show the Design Conditions or Existing Conditions, i.e., Input data. Columns 4, 5, 6 and 7 show the calculated effluent concentrations. The last two columns do not show on the Apple monitor, only on the printed report and show the percent removal for Method #2. (Note in the example, discharge #3 was not part of the WLA run since the trib switch was on).

The second report displays the water quality predicted for the design data and the WLA results. The last three columns, Unionized Ammonia, do not show on the monitor screen, only on the printed report.

In the example shown in Figure 12, above, the effluent concentration for reach #3 is unchanged at 50 and 3, i.e., mg/l of BOD-5 and NH_3-N, respectively, while the others have been reduced to 30 and 2.25. This discharger was removed from the allocation process, for illustration purposes here, by setting the TRIB SWITCH to "1", see Figures 7 and 9.

Swapping Data

Data management option #6 will take the results of either WLA method and copy it into the input fields for effluent BOD and NH_3. (The original data is retained and may be swapped back later.) This allows the user to run a DO profile of the results and use the reach reports to examine the proposed allocation. This collection of data may be altered, if desired, via the change option, and saved via the save option.

Figures 13 and 14 below show the results of swapping WLA results 1 and 2 into memory and then running a DO profile.

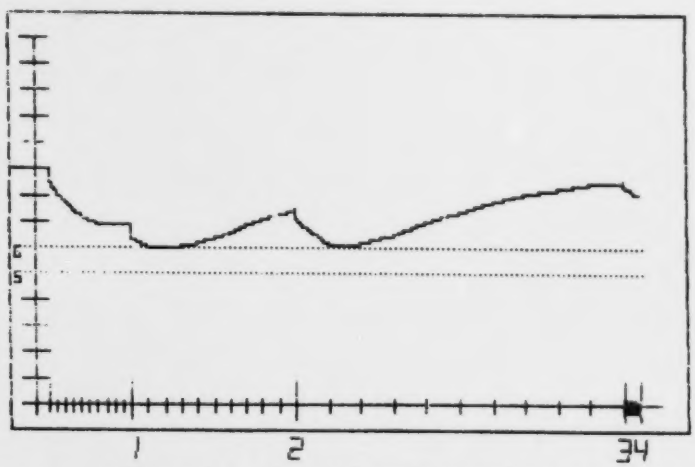

FIGURE 13 - RESULTS OF EQUAL EFFLUENT CONC. ALLOCATION

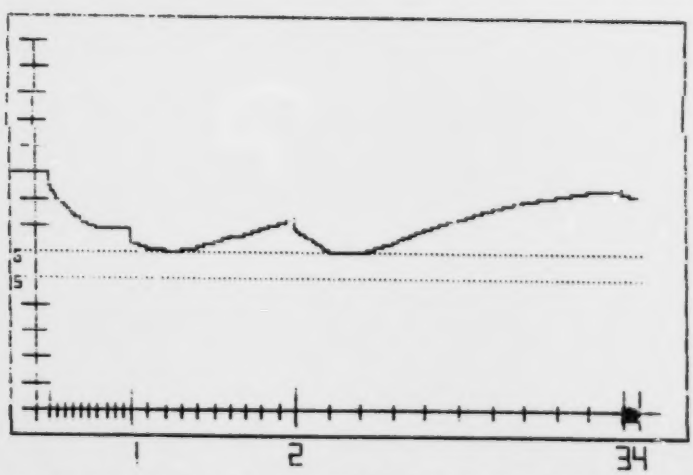

FIGURE 14 - RESULTS OF EQUAL PERCENT REDUCTION ALLOCATION

As the two figures show, both allocation methods avoided a DO violation.

The Allocation Process

The purpose of the allocation process, as per Section 95.3(f) is to "equitably allocate" some portion of an allowable load between point source dischargers. More specifically, to allocate the allowable load based on some set of future conditions. Note, however, that these future conditions are generally different from either the present conditions or the conditions described in the NPDES permits. The distinction between these different sets of conditions is critical and must be well understood before attempting to apply the WLA model.

Iteration Rules

Table 2 below lists the upper and lower limits for the WLA solutions and the step increment for the loops.

Method: Equal Effluent Concentration

	Starting Value	Ending Value	Step Size
BOD-5	30.0	1.0	-10%
NH3-N	15.0	0.5	-10%

Method: Equal Percent Removal

	Starting Value	Ending Value	Step Size
BOD-5	85%	99%	+2%
NH_3-N	20%	99%	+2%

TABLE 2 - LIMITS OF ALLOCATION LOOPS

The values listed in Table 2 are the default values contained in Release One of the WLA system (contained in Version #4 of the BWQM Modeling System). If you feel that other default values would be more appropriate, they could be changed for Release Two.

Conclusions

The current WLA model is a tool for performing allocations. It is currently good for two methods only; method #3, equal marginal cost above secondary, remains to be completed, and may not be included in the same computer program. Instead it will become a separate procedure.

The WLA model includes extensive data management capabilities. This is necessary since the allocation process is not a "cook book" event. Numerous manual iterations might be required to "play" with the data; testing for segment definition, refining allocations, performing sensitivity analysis or K-rates, etc.

Note on Release One - The programs which comprise the WLA System on Version Four of the BWQM Modeling System are labeled "Field Test". This is meant to convey a note of caution to all users. As in any new software, the users should watch for errors. Additionally, all users should examine the operating assumptions built into the system design.